Investigation of trace element geochemistry of moose (*Alces alces*) teeth apatite and possible links with increased incisoform breakage of Cape Breton Highland moose (*Alces alces andersoni*): A Pilot Study

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Abstract

Ungulates in the wild are normally free from periodontal disease. Yet, Cape Breton Highland (CBH) moose (*Alces alces andersoni*) of Nova Scotia have displayed an increased incidence of incisoform macro- and micro-fractures, which may have an effect on moose longevity. This condition appears to be rare, as it has only been formally documented in Alaskan (1992) moose (*Alces alces gigas*) and in Manitoban moose (*Alces alces andersoni*), and remains unexplained.

Furthermore, it has also been observed that the CBH moose are chewing their own fallen antlers, a condition known as osteophagia that is common within other ungulates but never before documented within moose populations, and they have also shown a marked increase in bark stripping activity. Both of these types of behaviour are usually associated with a dietary deficiency of some sort within other ungulate populations. Geochemical analyses of chewed fallen antlers from the CBH indicate that they have higher contents of calcium phosphate than those from the control area.

We have selected suites of broken and healthy teeth from the CBH and compared them with moose teeth from Shelburne County, NS, where no incidence of broken incisorform teeth has been documented. Fracture patterns in teeth, and especially tooth enamel (hydroxyapatite) were studied under the petrographic microscope and the electron microprobe. Enamel was carefully isolated from 25 representative samples of teeth from both the CBH and the control area and analyzed chemically by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Samples from the problematic CBH area are significantly depleted in Barium, Lead, Strontium, Cobalt and Tin when compared against the control area, and some of these deficiencies have been associated with dental disease in animals elsewhere. Samples from the CBH were divided arbitrarily into two groups: A) those collected north of the CBH National Park, and B) those collected south of the Park. In each case, they were separated with respect of their perceived low, medium and high degree of fracturing, which to some degree correlates with the increasing age of the moose.

Correlation trends based on breakage score and elemental concentration within the CBH are not always consistent. A) North of the Park increased degree of fracturing correlates positively with contents of Cd, Mn, Nb, Rb, Sr, Y, Sn and Bi, and negatively with Al, Cu, Ti, Zn, Mg, As, Th and U. B) South of the Park increased degree of fracturing correlates positively with Ba, Mn, Sr, Mg, Se, As, Y, Th and U, and negatively with Al, Cr, Cu, Ga and Sn. The number of samples is so far insufficient to draw statistically significant conclusions, yet these are the first multielement data available for moose teeth in the region, and raise interesting possibilities. For instance, the much higher concentrations of Sn determined in incisorform teeth of the healthy control group coincides with the relatively high Sn concentrations in rocks and soils in southwestern Nova Scotia, (e.g. East Kemptville tin mine) suggesting that the geochemistry of teeth may be used effectively as a forensic tracer of the source of illegally hunted wildlife.

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Chapter 1: Introduction

1.1 General Statement

For centuries, moose have been an important resource for native North American populations. Recently, within the last 10 years, an increase in incisoform breakage has been documented within the Cape Breton Highland (C.B.H) moose population, leading to concerns for the overall health of the herd.

A previous thesis carried out by Walsh (2003), assembled the background to this problem, and presented descriptive microscopy including that done by Graves and Casey (2002, unpublished). Walsh (2003) also presented some preliminary, yet inconclusive, geochemical data done at the slowpoke 2 reactor in early 2002, reaching the conclusion that the geochemistry on the moose incisor teeth should be a fruitful line of research.

This thesis, which supersedes the above-mentioned study, took over where Walsh (2003) left it, reassesses the nature of breakage, and provides geochemical data for the enamel of unhealthy teeth from C.B.H, and also for a control population in Shelburne County where there is no evidence of breakage. The study suggests that increased incisoform breakage and antler chewing are problems associated with nutritional deficiencies experienced by the CBH moose.

Recent findings also suggest that moose within the C.B.H herd are chewing their own fallen antlers (osteophagia), a phenomenon only ever recorded in other cervids, and the apparent first documentation of such behaviour within moose. There has also been an increased documentation of heavy bark stripping amongst the C.B.H population. Osteophagia is triggered by a phosphorous deficiency, whilst bark stripping is attributed to a depletion of preferred browse.

1.2 Introduction

Until recently, moose (*Alces alces americana*) were the dominant ungulate (Ungulate is Latin for “provided with hoofs”) within Nova Scotia (N.S), persisting throughout much of their historical range, despite a number of significant population declines over the last 300 years (Pulsifer and Nette, 1995). They have been an important resource for the native North Americans for centuries, long before Europeans arrived. Although it was the staple diet for many of the native communities, the hides and bones were just as important. The women worked the hides to provide valuable warmth during winters. The sinews yielded thread and glue, and the bones and antlers provided handles to knives and awls, as well as spoons and various other utensils (Franzmann and Schwartz, 1997).

When Europeans arrived during the early 17th century, moose were quickly recognized as being an easily obtainable source of food, tallow and hides, and subsequently they were substantially diminished by overharvesting and habitat loss (Pulsifer and Nette, 1995). Unrestricted moose harvests had a profound effect on moose populations within N.S. Two thirds of the mainland moose population were extirpated by the beginning of the 19th century, and the Cape Breton moose population was also in decline (Pulsifer and Nette, 1995).

During the mid 1800's, legislation was introduced that would manage and regulate the harvesting of the moose herds, which included the total ban on hide exports and protection of the cows, in hopes that the populations would recover to sustainable levels (Pulsifer and Nette, 1995). In 1874 the moose season was closed for the first time over concerns for the fluctuating population, and in 1877 it was reopened as mainland populations had increased. Irregular management practices followed that resulted in the moose populations to once again decline and resulted in another closure of the hunting season in 1937. Within 10 years of the closure the mainland population rapidly increased, peaked and crashed between 1949 and 1951 (Pulsifer and Nette, 1995). This resulted in local extirpation, scattered low density moose populations distributed across the mainland, and only two localized regions on the N.S mainland with relatively high density moose populations occurring within the Cobequid-Pictou-Antigonish Highland zones and the Tobeatic wilderness area (Fig 1.1a) (Pulsifer and Nette, 1995).

The moose population on Cape Breton Island did not experience the same success as the mainland populations from early management practices, never having recovered from a decline at the turn of the 20th century (Pulsifer and Nette, 1995). The reason for decline is not clearly understood, and was attributed to unregulated over harvesting of the herd, although this theory has become less popular in recent years because of the inaccessibility of the C.B.H. to the early hunters, and modern day hunters/people for that matter, and it is thought that the current day problems that are occurring within the herd could have been a contributing factor in the past (Nette, personal communication, 2004).

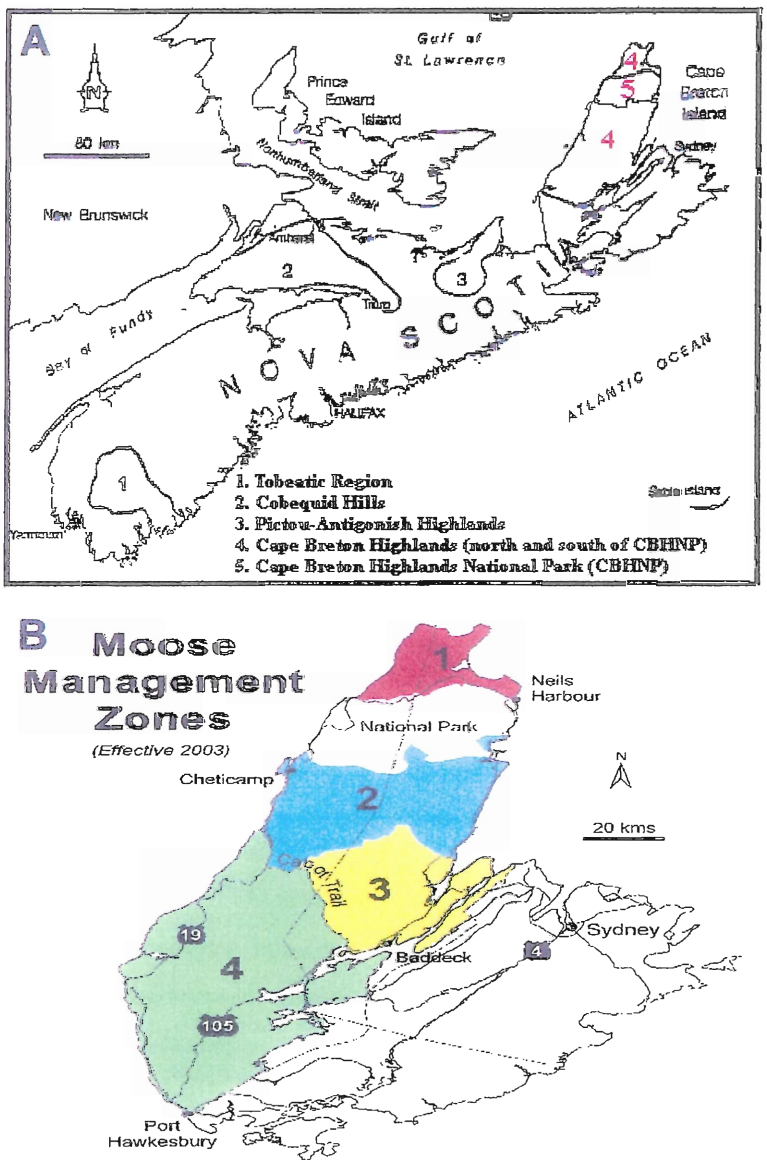


Figure 1.1 (A) Areas where moose populations have declined, are relatively abundant or high. Notice the control population (1) and the study population (4&5) (Pulsifer and Nette, 1995).
(B) Enlarged section of the study area, indicating new zones of management (Nette, personal communication, 2004).

During 1928 – 1929 an attempt at introducing 7 moose from the mainland into the western portion of the island to rebuild the herd proved unsuccessful. A second attempt was made in 1947 and 1948 with 18 moose from Alberta (*Alces alces andersoni*) being introduced within the Cape Breton Highland National Park (CBHNP) and this proved to be successful.

The introduced population, along with the possible remaining survivors of the eastern race, have formed the basis of the present Cape Breton Highland (C.B.H) population, which is now considered the largest and most stable population of moose in Nova Scotia (Figure 1.1a) (Pulsifer and Nette, 1995). The C.B.H herd is now known to be predominantly *Alces alces andersoni* (Broders et al, 1999).

1.3 Nature of the problem

During the past 10 years, hunters and managers of the Nova Scotia Department of Natural Resources (NSDNR), Wildlife Division have observed an increase of incisoform breakage prevalence, that is particularly noticeable within the I1 and I2 incisors of the moose. Observations and documentation have been made on teeth that have been submitted by hunters. The gradual degradation of the teeth has implications for the overall health and vitality of individual moose within the herd, and appears to be playing a role in the poor representation of older aged moose within the population (Nette, personal communication, 2004).

1.3.1 Study Area

Cape Breton Island was recently (2003) divided into four regions for the purposes of moose management (Figure 1.1b), 1. North of the Park, 2. South of the Park, 3. Baddeck; Margaree, Hunters Mountain to Fraser Mountain Road and 4. Cabot Trail south to Port Hawkesbury. The focus of this study is based on the older management zones of Figure 1.1a, located in northern Cape Breton Island, northern N.S. The highland region is approximately 2400 km^2 (Pulsifer and Nette, 1995).

South of the Park is the largest of the three regions with a land area of 1220 km^2, CBHNP has an area of 950 km^2, and the area north of the park is the smallest with a land area of only 230 km^2 (Pulsifer and Nette, 1995).

The CBH's is a characteristic boreal region (Pulsifer and Nette, 1995), with a combination of dense spruce, blanket bogs and barrens that provides habitat for boreal species such as moose, snowshoe hare and lynx (Canadian Geographic, 2004). Black bear and cougar are the large carnivores that survive in generally undisturbed portions of habitat (Canadian Geographic, 2004). It is represented by the highest elevation within the province of Nova Scotia (370m), and also receives the highest annual precipitation for the province, over 1600mm annually (Environment Canada, 2004). During winter, more than 400cm of snow may fall in the region, with the snow pack usually lasting from early or mid November to April-May (Museum of Natural History, 2004). Because no weather stations exist in the regions of high elevation, reliable weather data are not available for the highlands. However, it is known that many days of the year the highlands are covered in a dense fog that results in relative high humidity. The high elevation contributes to a harsh climate for the CBH that results in a short growing season, but tree growth is rapid, except where strong winds stunt growth on exposed ridges (Museum of Natural History, 2004).

The coastal lowlands of Cape Breton are typical of cool, wet, acidic conditions dominated by spruce and fir trees, with the major influences on the regional vegetation resulting from marine climate and extensive disturbances by fire and cutting (Canadian Geographic, 2004).

1.4 Purpose

This project has been ongoing for five years, with little hard results or conclusions to date (Walsh, 2003). Through the combined efforts of Dalhousie University and the NSDNR, wildlife division, this thesis conducted a preliminary study of the tooth enamel from the C.B.H moose and tooth enamel from the moose of the Tobeatic herd. The Tobeatic herd is used as a control; where there is currently no evidence to suggest that these moose are experiencing the same problems as the C.B.H herd in regard to incisoform breakage. To accomplish this we analysed for trace elements within the enamel to determine if the moose are deficient/excessive in trace elements, some of which have been previously implicated in both dental studies and physiological studies based on controlled experiments and observations conducted on human and animal populations. Trace elements can be naturally occurring within the environment or also from anthropogenic sources.

1.5 Importance

1.5.1 Annual Harvest

The moose herd in C.B.H is the largest and most stable population within the province of N.S., and is therefore the only area within the province that an annual moose hunt is conducted. Since 1982, other regions of N.S have been closed to hunting (Pulsifer and Nette, 1995) because current herd populations are not stable enough to support sustainable harvesting. It is important for the C.B.H herd to remain at sustainable levels for hunting to continue in the area. Native people of the area still rely on the herd for sustenance and ceremonial purposes (Nette, Personal communication 2004), while the annual hunt also supports numerous big game hunters. The native harvest is unregulated and quite high, with no hard numbers available. From 1986 to 2002 the regulated hunt offered 200 licences a year based on a lottery system with an average of 11,500 to 16,000 applications a year (Nette, personal communication, 2004).

1.5.2 Physiology

Another aspect of importance is moose physiology and browsing habits. Moose, like other ungulates, lack upper incisors. Moose rely on their lower incisors (Figure 1.2a, Figure 4.2) when foraging for food, especially in winter months when vegetation is relatively poor quality woody vegetation (Franzmann and Schwartz, 1997). Woody twigs and branches are cropped and stripped off of their source by placing the vegetation between the incisors and upper maxillary bone (Figure 1.2b).

Increased bark stripping of hardwood species has also been observed within the C.B.H moose, which is strong evidence that suggests moose are close to or have exceeded their carrying capacity (Nette, Personal communication, 2004) as this type of behaviour is usually a response normally associated with food shortage in late winter when preferred browse is unavailable (Franzmann and Schwartz, 1997).

Fracturing is only evident within the incisors, and not the molars. Such fracturing that occurs severely inhibits a moose's foraging ability in winter months, and can lead to severe malnutrition, or in severe cases death of the animal. Moose need to maintain their large body size to meet the demands of changing thermal conditions of their environment (Franzmann and Schwartz, 1997). It is because of the large body size that moose are extremely tolerable of cold conditions, as the large body size acts as insulation (Franzmann and Schwartz, 1997).

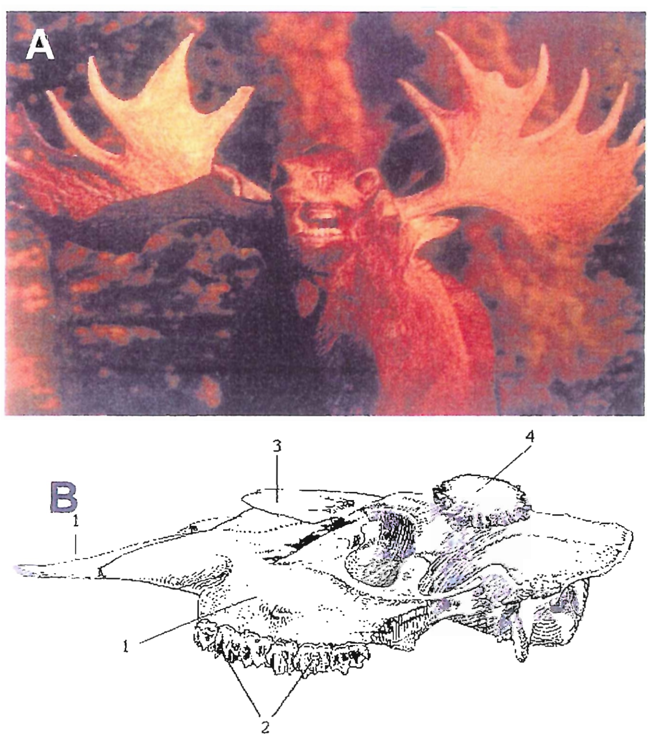


Figure 1.2: (A) Frontal view of Bull Moose displaying lower incisors and upper maxillary (Franzmann and Schwartz, 1997)
(B) Lateral view of a Bull Moose cranium. 1 = maxillary bone, 2 = upper molars, 3 = nasal bone, 4 = antler shaft. Notice that the upper jaw lacks incisors (Modified from Franzmann and Schwartz, 1997)

1.5.3 Osteophagia

There is also evidence to suggest that moose are chewing on their fallen antlers, a phenomenon that is usually only seen to occur within other ungulates, and not moose (Nette, Personal communication, 2004). It is important to document this phenomenon, which is believed to be the first known evidence to suggest that moose eat their own fallen antlers (Nette, Personal communication, 2004).

1.5.4 Wildlife Forensics

This project analysed within moose teeth enamel for trace elements. The project will investigate tooth breakage in the C.B.H moose, and explore the hypothesis that breakage may be a reflection of the trace element content of the enamel, a result of moose chewing their fallen antlers (Osteophagia), the stripping of hardwood bark, or even a combination of two or all three of these factors.

The results of geochemical analysis may be of significance in regard to the developing field of Wildlife Forensics. Analysis of the data may show distinguishable populations based on the trace element composition of the tooth enamel. The Control population on the mainland portion of N.S has been dwindling in numbers, and was recently listed as "endangered" under the Nova Scotia Endangered Species Act. Illegal hunting is an on going problem with the dwindling population (Nette, personal communication, 2004). Under the Nova Scotia Endangered Species Act, any persons that are found guilty of disturbing, killing, injuring, possessing, taking or interfering with or attempting to kill, injure, possess, disturb, take or interfere with an endangered or threatened species can now be charged upwards of $500,000 and possible imprisonment in accordance with the Endangered Species Act (Endangered Species Act, Chapter 11, sects 13; 22-26).

If successful, this study will demonstrate how it is possible to determine from which area a moose originated (lived). At present, it is difficult if not impossible to prove in a court of law, where a moose from within Nova Scotia originated. DNA can be used but only if DNA structure of the source population, as well as the alleged source population and other possible source populations are known (Nette, personal communication, 2004).

1.6 Previous Work

Incisoform wear in moose populations of North America appears to be a rare condition, as it has only been formally documented twice before. Previous accounts of tooth wear in moose were illustrated in two separate studies, one conducted on a population of moose in Manitoba and the other in Alaska. Both studies documented different aspects of causation to tooth wear, and a brief discussion of each will follow.

The C.B.H moose were previously studied. A thesis, conducted by Walsh (2003), described the Micro and Macro fracturing of moose teeth, and also attempted to link the geochemistry of C.B.H to the increased incidence of incisoform breakage by utilising microprobe and Neutron Activation Analysis (NAA). Both microprobe and NAA results indicated a correlation between trace element content and fracturing, with fractured teeth indicating a relative depletion of Zn, Sr, Au and Ba. However, the results by Walsh (2003) were not proven to be statistically significant.

Phil Casey, funded through the Natural Sciences and Engineering Research Council of Canada (NSERC), completed a descriptive study on of microscopic breakage within the enamel framework of the C.B.H population. His worked has been continued in the present thesis.

In Alaska, Smith (1992) examined 270 mandibles from a population of moose (*A. a. gigas*) in the Seward Peninsula. Mandibles containing incisors were collected during the 1988-1990 hunting seasons. All moose were aged by cementum annulus analysis. Breakage score was determined by the amount of tooth material that was lost on a scale of 0-5. 0=unbroken, 1= 15% or less missing, 2 = 15-25% lost, 3 = 25-35% lost, 4 = 35-50% lost, and 5 = 50% or more lost.

Smith (1992) did show a positive correlation for moose age and incisoform breakage, although he did not go into great detail describing the fractures. Zn, Cu, K, Co, Fe, Pb, Ca, Mg, Na, Cd, Mn, Cr, Mo, Se, and Al were analysed using Microbeam analysis. Analysis of 40 teeth harvested from the Seward Peninsula, and 20 moose harvested near an area called Galena (areas where moose rarely have broken teeth), did not exhibit any significant differences in trace elements.

Smith (1992) realised that the significance of incisoform breakage to the welfare of the Seward Peninsula moose population is unknown. The concluding factor to the incidence of incisoform breakage within the moose population of the Seward Peninsula was determined by Smith (1992) to be possible early symptoms of density related (overpopulation) problems amongst the moose.

Young and Marty (1986) described 'excessive tooth wear' within a population of Manitoban moose (*A. a. andersoni*). Thirty-five moose from the 1983-1984 annual moose hunt were the subject of their study, 16 displaying tooth wear and 19 controls that did not exhibit tooth wear. Moose were aged by cementum annulus analysis. A detailed description of the incisors was documented.

Crown heights, percent tooth loss, interfacet distance, facet area and microwear were all analysed by Young and Marty (1986). Their methods of analysis for crown height, tooth loss and interfacet distance are very in depth, and the paper should be consulted as it is well beyond the scope of this project. The microwear was studied using a Phillips scanning electron microscope 505 at magnifications of X10 to X700. Teeth were examined for the extent of enamel and dentin loss, the orientation of the wearing forces from striations and also the direction of wear. It is important to mention that the type of 'tooth loss' observed by Young and Marty (1986) is analogous to the fracturing within the CBH moose.

Young and Marty (1986) showed that there were significant ($P<0.001$) differences between crown heights, percent tooth loss, and interfacet distance between the affected moose and the control. The microwear favoured abrasion by particulate matter of a greater hardness than dentine or enamel. Noting the moose's browsing habits of aquatic vegetation and woody stems and leaf litter, Young and Marty (1986) noted the possibility of high silica content as being likely source for an abrasive agent, which were inferred to have a minimum size of 1.5μm

No chemical analysis was performed on the teeth. Young and Marty (1986) recommended a field study of the affected moose population by a ruminant biologist, also a direct study of moose feeding habits and local vegetation, and indirect studies of their diet by dung analysis to solve the problem.

1.8 Limitations

The current project is intended as being a pilot study. Based on this approach, the project had limited funding and therefore limited samples were analysed, although those samples analysed are considered as being representative of the populations.

Unfortunately, no comparisons could be made with other moose studies in relation to trace elements present, only against the literature that contained studies on humans and animals. This limits our ability to draw solid conclusions, as biological trace element values from one species to another is always open to question.

1.9 Organization of Material

This thesis is divided into seven chapters. The introductory chapter briefly outlines the focus of the study and why it is of importance. The second chapter provides an overview of moose, with particular attention paid to habitat, nutritional requirements, and affects of antler growth and reproduction. Chapter three describes teeth in detail; tooth mineralization, enamel structure, dental caries and the importance of trace elements in relation to dental caries. Chapter four and five focus on moose teeth, describing Macro and Microfracturing respectively. Chapter five also with the geochemistry of moose teeth, with attention paid to the results of ICP-MS analysis. From the results, comparisons are made in reference to the literature and possible conclusions are drawn.

Chapter five provides full descriptions of microfractures as described by Graves and Casey (2002, unpublished), and introduces new data followed by discussions and conclusions. Chapter six attempts to correlate the geochemistry of moose teeth with the geology/geochemistry of the Cape Breton Highlands, and southwest Nova Scotia. The final chapter draws together all the information and conclusions are drawn based on this study, and provides recommendations for future work.

Chapter 2: Nutrition and Antlers

2.1 Introduction

Ungulates comprise one of the most successful and diverse groups of large mammals alive today, inhabiting every continent except Antarctica and Australia (The Ultimate Ungulate Page, 2003). Ungulates belong to the **Kingdom** Animalia and The **Phylum** Chordata (Subphylum vertebrata). More Specifically, moose are classified as follows: **Order** Artiodactyla (Or 'even toed'), **Suborder** Ruminantia (Four (sometimes 3) stomach chambers), **Infraorder** Pecora, **Family** Cervidae (Deer, with shedding antlers), **Subfamily** Odocileinae, **Genus** Alces, **Species** Alces alces (Franzmann and Schwartz, 1997; The Ultimate Ungulate page, 2003).

Ruminants, such as moose, are considered to be the most advanced of the Artiodactyla having four (sometimes three) stomach chambers that allow for the proliferation of micro organisms that allows for the digestion of tough vegetation, which would otherwise be unavailable to the animal (The Ultimate Ungulate Page, 2003).

Moose are found only in the Northern Hemisphere, occurring in Canada, U.S.A, Russia, Finland, Sweden, Denmark, Norway, Lithuania, Estonia, Poland, Czechoslovakia, Manchuria and China occupying the vast, global band of Northern boreal forest dominated by spruce, fir and pine trees (Odum, 1983; Telfer, 1984, in Franzmann and Schwartz, 1997). They belong to the suborder Ruminantia, and Genus *Alces* (Alces = Latin for elk) (Franzmann and Schwartz, 1997).

Modern North American moose appear to have originated from Siberia, yet the timing of their North American invasion across Beringia is still disputed. Many people have hypothesised to the exact timing of invasion, ranging from the end of the last glaciation (10,00-14000 years B.P), to the peak of the Wisconsinian glacial period (~18,000 years B.P) (Franzmann and Schwartz, 1997). Although moose have been present on the North American continent for thousands of years, they still continue to exploit new range and territory. It is only recently that they have invaded eastern portions of North America such as Labrador, where the first sightings occurred in this region in the early 1950's (Chubbs and Schaeffer, 1997).

2.2 Habitat

Moose can thrive in a variety of habitats, including montane forest and ripariarian communities characteristic of the Northern Rocky Mountains, mixed deciduous hardwood forests of north central and northeastern portions of the United States, and aspen-dominated boreal forests of Canada and boreal forests of Canada and Alaska (Franzmann and Schwartz, 1997). The limiting factors of a moose's geographic distribution are food and cover to the North (Kelsall and Telfer, 1974, in Franzmann and Schwartz, 1997), and climate to the south (Renecker and Hudson, 1986, in Franzmann and Schwartz, 1997).

Abundant woody vegetation is a common link between these characteristic ecoregions and characteristic of most, if not all, moose habitats and is especially an important feature for wintering moose who rely on the availability of these woody plants as a food source (Franzmann and Schwartz, 1997). C.B.H moose inhabit areas ranging from boreal to mixed forest, bogs, rivers lakes and streams.

2.3 Extent of Territory

A home range of a moose represents an area that is familiar to the moose, where the moose can feed, rest, escape predators and meet its other life requirements, and moose tend to return to these areas (or remain in the same home range) for many years (Franzmann and Schwartz, 1997). The C.B.H moose will range approximately 40km^2, and stay close to an abundant food source in the winter, restricted by snow cover, and during summer months they will range further in search for more succulent food (Nette, Personal Communication, 2004).

2.4 Forage / Browse

The moose is a herbivore that is considered a "generalist" browser, who will ingest moderate amounts of a variety of vegetation such as leaves and bark, shrubs, woody twigs, and aquatic vegetation, as opposed to "specialist' browsers which consume high levels from only a few plant species (McArthur et al. 1991, in Franzmann and Schwartz, 1997). Moose, like all browsers, are equipped with narrow muzzles, prehensile lips and tongues that allow for high quality selection of small plant parts for ingestion. The type of vegetation a moose ingests is dependant on the seasons, and must also meet certain criteria. According to Oldemeyer (1974), forage must be highly palatable, have optimum levels of various nutrient components, have high apparent digestibility of nutrient components, have optimal proportions of volatile fatty acids, have adequate levels of minerals, vitamins and trace elements, and finally be efficiently converted into components necessary for the animals bodily functions.

Moose will consume plant parts from a variety of species, although the majority of moose foods are classified as browse (Woody plants). (Franzmann and Schwartz, 1997).

2.4.1 Spring-Summer

Vegetation growth is at its peak during the warmer months of spring and summer. North American moose will usually rely on deciduous tress and forbs, which are quick growing annual species such as cloudberry (*Rubus chamaemorus*), sundew (*Drosera rotundifolia*), fireweeds (*epilobium angustifolium*) and lupine (*lupinus nootkatensis*) (Peek, 1974). Mushrooms and aquatic plants are considered succulent foods for moose, and moose will also feed on such species when they are present (Peek, 1974)

As seasons change, so does the quality of nutrients available within plant tissues. Actively growing plant tissues represent the highest quality foods available to moose, and they begin their growth phase in early spring, long before actual green-ups occur (Franzmann and Schwartz, 1997). This is due to the translocation of nutrients from the roots to the twigs and swelling buds that will turn to leaves, and represents a time of rapid increase in the plants nutritive value (Franzmann and Schwartz, 1997). As the plant nears maturity, plant tissues mature and more structural carbohydrate is manufactured, thus decreasing forage quality for moose (Franzmann and Schwartz, 1997).

No detailed information was available on the spring-summer forage preference of Nova Scotia moose populations.

2.4.2 Autumn-Winter

Fallen leaves are an important food source in early autumn for moose. By consuming freshly fallen leaves in early autumn, a higher digestibility rate is realized than from woody twigs alone, and in addition this food resource can be exploited with minimal amount of travel in areas where high stands of forage biomass occur (Renecker and Hudson, 1985; Franzmann and Schwartz, 1997). However, feeding on this resource declines when snow cover restricts access, and also when more nutritious food becomes available in early spring (Franzmann and Schwartz, 1997).

Moose are inclined to sample new plants they locate (Franzmann and Schwartz, 1997), so therefore browsing habits for moose will vary geographically. A 1996 browsing survey for moose in C.B.H by Basquill and Thompson (1997) revealed moose preferred foraging woody plant species that occurred in the dense undergrowth during winter months. These included deciduous woody plants, such as mountain, red, and striped maple, red buried elder, mountain ash, white birch, and shadbush (Basquill and Thompson, 1997).

Bark stripping is a behaviour amongst ungulates that occurs when areas support poor winter browse, when food is in short supply in late winter when preferred foods are unavailable or when animals are restricted by deep snow cover. Moose perform this task by taking their lower incisor teeth and racking them perpendicular to the tree trunk (Figure 2.1), which is different from the technique used by elk, which normally bark trees by racking the lower incisors vertically along the trunk (Franzmann and Schwartz, 1997). This food source does not normally comprise a large portion of the moose diet and usually is considered a "starvation" (last resort) food (Franzmann and Schwartz, 1997). Bark stripping is not a common behaviour for moose, and is very rarely observed within populations (Nette, personal communication, 2004).

However, Renecker and Hudson (1985, in Franzmann and Schwartz, 1997) observed moose in Alberta stripping bark mainly from aspen during early spring. This behaviour corresponded with warmer temperatures and the apparent movement of soluble sugars, which is highly palatable and easily absorbed by the moose's digestive system, up the stem of the plant.

Bark Stripping by C.B.H moose is increasingly evident, especially in areas where moose densities are higher and very heavy browsing of preferred vegetation is evident (Nette, personal Communication, 2004). This could be a sign of moose populations in the area having reached, or even exceeded, their carrying capacity (Nette, personal Communication, 2004).

Figure 2.1: Bark stripping occurs in moose when there is a depletion of preferred browse, or when snow cover restricts the animal. Moose strip bark from trees by racking their teeth perpendicular to the trunk. (Photo by Charles C. Schwartz; Alaska Dept. of fish and game, *In* Franzmann and Schwartz, 1997).

2.5 Nutritional Requirements

Due to their large body size, moose must consume large quantities of food, and because of these large food requirements they must find, consume, and digest food at a rapid rate (Franzmann and Schwartz, 1997). Many factors need to be considered when evaluating forage for moose, such as amounts, availability and nutritional value. For moose, the nutritive value of plants is related to the essential nutrients that they contain, including carbohydrates, fats, water, protein, vitamins and minerals (Franzmann and Schwartz, 1997).

For the purpose of this study, we will be focusing on nutritional requirements in relation to minerals. Minerals are a diverse group of nutrients that play an essential role for moose growth, health, and well being. Calcium, phosphorous, sodium, potassium, magnesium, chlorine and sulphur are minerals that are required in large amounts (mg / g), and are classified as macronutrients (Franzmann and Schwartz, 1997). Minerals required in small amounts are referred to as trace elements, and very little is known about the trace element requirements by moose (Franzmann and Schwartz, 1997).

Minerals will tend to vary in concentration between plant species, and also vary in concentration within a single plant organism. Many species tend to accumulate elements within their leaves or stems, and this differing elemental concentration between different sections of a plant species is important because elemental imbalances can have an impact on moose nutritive health than the absolute amounts present within the plant (Kubota, 1974).

A variety of high quality forage is an important factor in a moose' diet. A study conducted by Ohlson and Staaland (2001) considered the mineral diversity in wild plants, and the benefits to moose. Their study concluded that a diversity of plant species is required for a diversity of minerals for moose, and that feeding on few plant species may result in a deficient, or even toxic mineral nutrition. It is important for large herbivores, such as moose, to feed on a wide spectrum of plants to obtain essential minerals, not only in sufficient amounts, but also in physiologically balanced proportions (Ohlson and Staaland, 2001), because it is possible for plants to hyper accumulate certain minerals, or oppositely plants may not absorb sufficient quantities of minerals. So therefore, when moose limit themselves to very few forage species, or they are forced to limit their foraging due to external factors, they are put at risk of element deficiency/toxicity.

2.6 Antlers

Antlers are composed of hydroxyapatite, a crystalline calcium phosphate (Franzmann and Schwartz, 1997). Bull moose will begin antler growth in April – March and cease to grow in August (Nette, personal communication, 2004). This has a huge strain on the mineral resources of a moose's body. During antler growth, calcium and phosphorous are resorbed from bones because dietary intake and absorption of these minerals is insufficient to meet mineralization requirements (Banks et. 1968, Hillman et al. 1973, Muir et al. 1987; in Moen and Pastor 1998). This can severely impact the health and well being of the moose because shortly after mineralization of the antlers, moose will enter the rut, and during this period will not eat (Franzmann and Schwartz, 1997), therefore not replenishing any loss of minerals from bones used to support antler growth. This is significant because serious injuries, such as broken bones already weakened by mineral deficiencies, may result due to the characteristic sparring of Bull Moose that occurs during the rut.

Once antlers have been shed, which usually occurs by December for mature bulls (Nette, personal communication, 2004), the mineral constituents of the antlers that are stored are lost to the moose, however, rodents and other animals benefit from chewing antlers to obtain minerals for themselves (Franzmann and Schwartz, 1997).

Bulls do not grow prime antlers until they reach the ages of 5-12 (Franzmann and Schwartz, 1997). Antlers are first apparent in the bull when the calf is 6-7 months old, when tiny thumb-like antlers appear (Franzmann and Schwartz, 1997). When the moose is at one year of age, it will grow a second set of antlers that will be visible, and occasionally palmation of the antlers will occur, with three or more points (Franzmann and Schwartz, 1997). At 2-4 years of age, sub mature bulls will grow their third to fifth antler sets, which will be characterized by small palms (Franzmann and Schwartz, 1997).

2.7 Nutritional Requirements of Antler Growth and Reproduction

The following discussion has been taken from Moen and Pastor (1998), unless otherwise noted.

There is very little work documenting the nutritional and energetic requirements for moose during the mating season. Moen and Pastor (1998) concluded that antler growth in bulls required up to 25% more energy than the normal basal metabolic, and that a cows requirements for gestation and lactation increased their energy requirements by up to 35%. Protein requirements for the growth of antlers in bulls, and gestation and lactation in cows are most likely met by forage intake and, as mentioned, Ca and P are resorbed from the bones.

2.8 Osteophagia in C.B.H moose

Osteoporosis in moose has been documented from skeletal remains in moose populating the Isle Royale National Park, Michigan (Franzmann and Schwartz, 1997). Observations of antler chewing (Osteophagia) by moose were made in the C.B.H during 2001 (Roger and Nette, 2002). This phenomena has been visually verified (Nette, personal communication, 2004) and also, by preliminary fieldwork by Roger and Nette (2002) inspecting 98 shed antlers, found that over 30% of shed antlers in the C.B.H had been chewed by moose within one month of antlers becoming available after snowmelt (Figure 2.3a). This appears to be the first documented case of osteophagia in moose (Nette, personal communication, 2004).

Evidence suggests that osteophagia is an innate, rather than learned behaviour, which is triggered by a deficiency of phosphate (Denton et al. 1986) that is widespread amongst artiodactyls (Sutcliffe, 1973). Osteophagia occurs in natural conditions and has a distinct geographical distribution that is dependant on the parent rock in which the plants are growing, but can also be influenced by the occurrence of excessive amounts of calcium, aluminium or iron, which can reduce phosphorous availability to plants (Sutcliffe, 1973).

This behaviour probably presents some inconvenience to the cervidae that exhibit this behaviour, as it reduces time spent grazing, may cause injury to the mouth, and infection by bacteria in the case of bones still covered by rotten flesh, and certainly enhances teeth wear (Sutcliffe, 1977; Denton 1982; both in Barrette, 1985).

Characteristic patterns have been documented in antlers chewed by ruminants such as deer, that produce characteristic fork patterns at then end of the antler (Figure 2.2a), and zigzag margins at the proximal end have been documented (Figure 2.2b) (Sutcliffe, 1973).

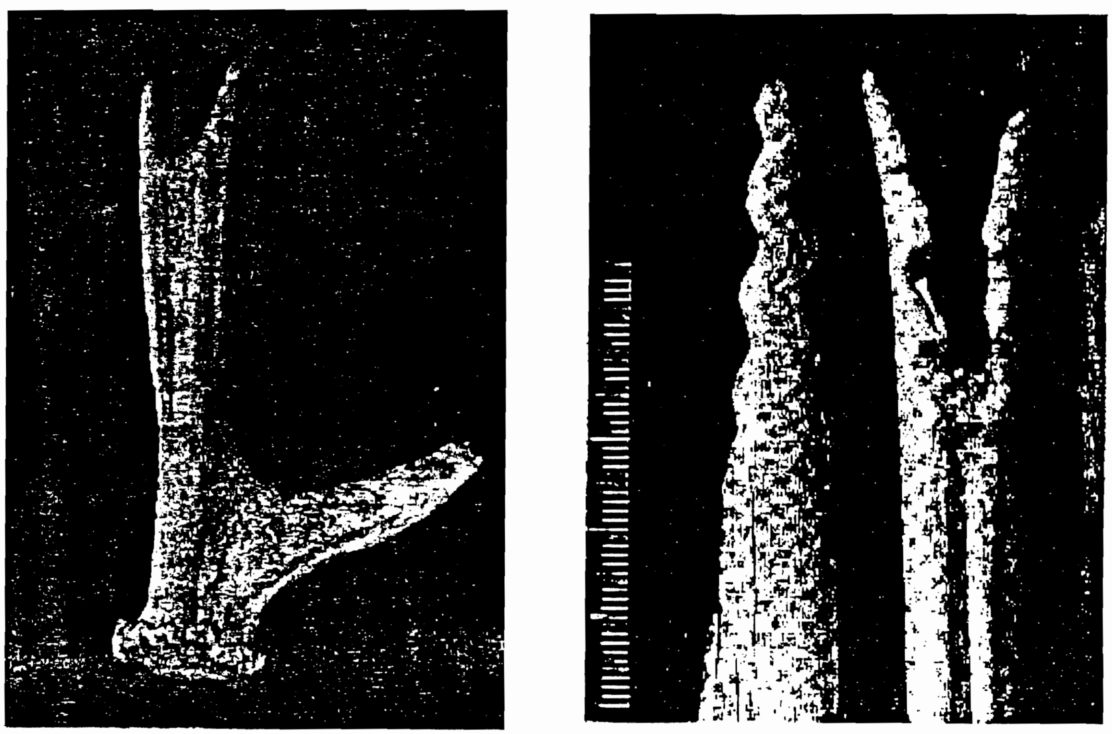


Figure 2.2 (A) Red Deer antler chewed by wild Scottish red deer to create a "fork" pattern.
(B) Norwegian Reindeer metatarsal chewed to create 'fork' with zigzag margins at its proximal end. (Pictures from British Museum (Natural History); In Sutcliffe, 1973)

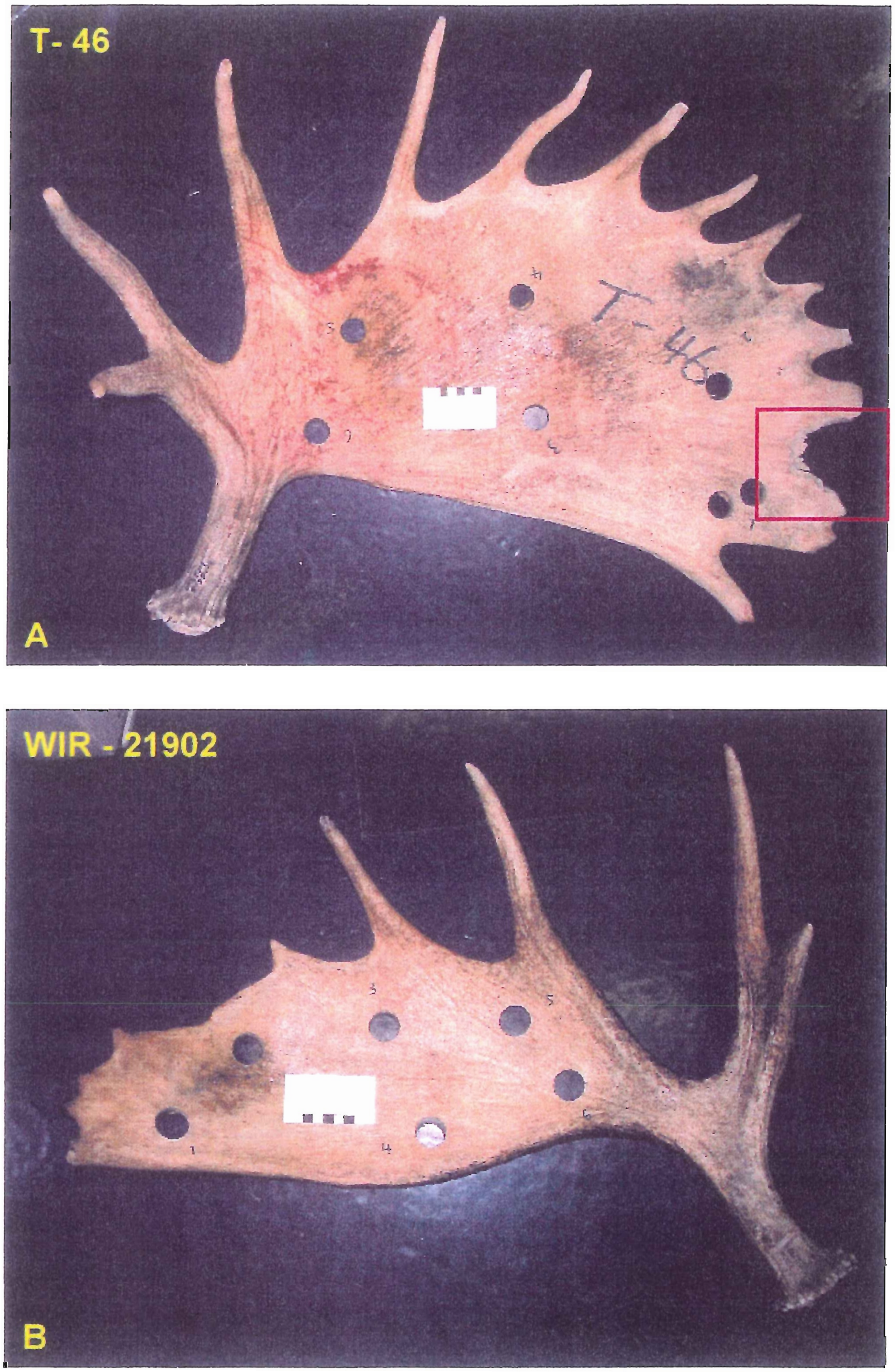


Figure 2.3 (A) Antler from C.B.H, notice the chewed section highlighted in the box. Holes represent core samples taken for geochemical analysis (B) Un-chewed antler from the control area. There is no evidence of chewing having occurred on this antler. Holes represent core samples taken for geochemical analysis.

During a limited (2 day) study within the C.B.H, Roger and Nette (2002) found several antlers that displayed characteristics of being chewed upon by moose within the area (Nette, personal communication, 2004). The nature of these chews and marks did not appear to be the result of rodents, carnivores or black bear as these animals will not leave the characteristic pattern due to different chewing techniques, that usually involve the very tips of the antlers (Nette, personal communication, 2004). White-tailed deer, the only other cervid in the province, seldom inhabit areas of higher elevation such as that of the C.B.H, as snow depth is a restrictive factor (Roger and Nette, 2002). According to Roger and Nette (2002), there was no evidence of deer having been in the area of investigation.

2.9 Methods

Two antlers were received from the NSDNR, Wildlife Division, for geochemical analysis (Figure 2.3). T-46 has been chewed upon by a moose, and comes from the C.B.H (Figure 2.3a). WIR-21902 is an unchewed antler that comes from a herd in the Tobeatic Wilderness Area of Shelburne County (Figure 2.3b).

Six drill core samples were taken from each antler, representing various sections of the antler, and were analysed using atomic absorption spectrometry (AAS), Minerals Engineering Center, Dalhousie University.

2.9.1 Atomic Absorption Spectrometry (AAS)

The following has been taken from Hughes et al (1976) unless otherwise noted. Atomic Absorption Spectrometry is analytical technique that measures a wide range of elements within a given sample. The process requires very small sample sizes, typically ~10mg, that are dissolved in strong acids. Therefore, the technique is destructive of the sample, but little damage is caused to the source due to the very small samples needed. Spraying the resulting solution into the flame of the instrument, which is consequently atomonised, results in measurements of elements. Light of a suitable wavelength for a particular element is shone through the flame, and the atoms of the sample absorb some of this light. The amount of light absorbed is proportional to the concentration of the element in the solution, and hence in the original object. Figure 2.4 is a schematic diagram of a typical AAS machine.

To achieve complete analysis of a sample, each element is scanned for separately, thus the spraying technique is repeated several times according to the number of elements of interest. Therefore, the technique is time consuming but it is possible to detect trace elements to parts per million (ppm) level.

2.10 Results

AAS analysed for 26 trace elements within both sets of antlers (Table 2.1). The results show that there are generally higher representations of Ca, P, and Mn within the C.B.H antler that has been chewed compared to that of the unchewed antler from Shelburne County. The unchewed antler shows generally higher representation of C, Ba and K compared to the chewed antler of C.B.H. Figure 2.5 shows a plot of Ca versus P between the two antlers, and from this we can see that there are two distinct populations.

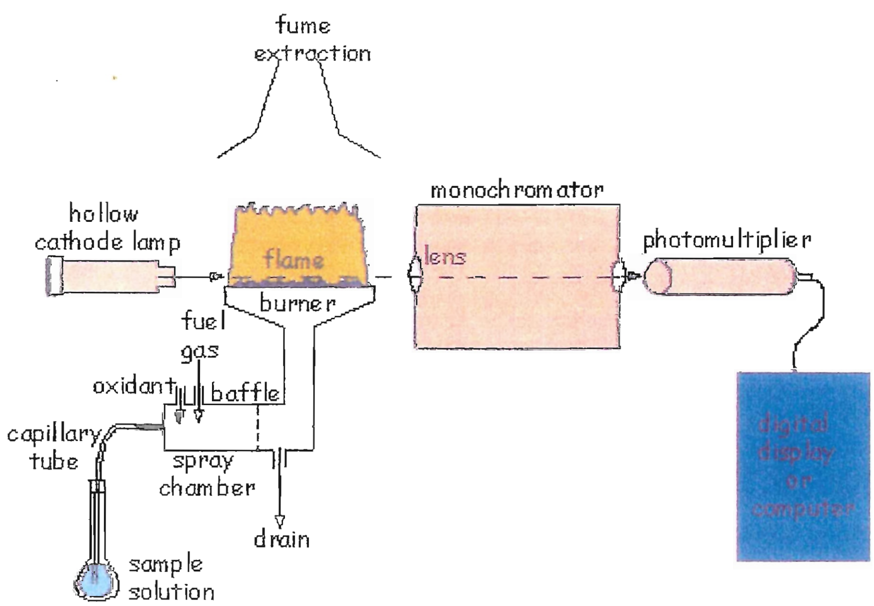


Figure 2.4: A typical Atomic Absorption Spectrophotometer (Hughes et al, 1976).

Table 2.1 : Geochemical Results for Antler Analysis

T-46							WIR 21902						
Si %	0.15	0.84	0.24	0.22	0.21	0.11	Si %	0.12	0.34	0.29	0.28	0.21	0.18
Ti %	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	Ti %	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Al %	0.025	0.046	0.021	0.042	0.017	0.023	Al %	0.035	0.03	0.013	0.011	0.011	0.014
Mg %	0.34	0.27	0.34	0.44	0.46	0.53	Mg %	0.3	0.26	0.26	0.28	0.29	0.31
Ca %	26	24.94	26.95	27.11	27.46	29.1	Ca %	16.7	15.92	15.31	17.45	10.57	17.8
Na %	0.24	0.22	0.25	0.26	0.27	0.36	Na %	0.19	0.16	0.18	0.28	0.3	0.36
P %	9.82	9.43	9.78	9.73	9.95	9.99	P %	6.81	6.37	5.78	6.33	5.94	6.76
C %	18.37	18.56	17.93	17.88	17.61	16.74	C %	27.12	29.74	30.09	28.67	29.8	28.11
As ppm	4	4	2	5	4	4	As ppm	2	3	2	3	8	2
Ba ppm	260	220	230	240	220	240	Ba ppm	380	380	340	340	350	350
Be ppm	<1	<1	<1	<1	<1	<1	Be ppm	<1	<1	<1	<1	<1	<1
Cd ppm	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	Cd ppm	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Co ppm	<1	<1	<1	<1	<1	<1	Co ppm	<1	<1	<1	<1	<1	<1
Cr ppm	14	30	19	15	18	22	Cr ppm	12	24	24	29	19	19
Cu ppm	4	5	5	3	5	5	Cu ppm	4	5	6	5	4	3
Fe ppm	844	1950	1200	838	1060	1170	Fe ppm	568	1470	1610	1830	1180	1010
K ppm	95	87	84	67	65	134	K ppm	104	75	158	288	293	309
Li ppm	4	3	5	5	5	5	Li ppm	3	3	3	3	3	3
Mn ppm	37	62	59	88	89	42	Mn ppm	14	17	18	17	17	15
Mo ppm	<1	<1	<1	<1	<1	<1	Mo ppm	<1	<1	<1	<1	<1	<1
Ni ppm	2	4	3	2	1	1	Ni ppm	<1	<1	2	3	5	2
Pb ppm	6	5	<2	<2	6	<2	Pb ppm	4	4	2	3	2	3
Rb ppm	6	8	5	6	3	5	Rb ppm	2	2	2	4	4	4
Sr ppm	285	264	315	318	331	313	Sr ppm	366	358	361	403	381	408
V ppm	8	9	9	8	9	7	V ppm	8	5	6	9	8	7
Zn ppm	113	104	101	100	100	100	Zn ppm	113	109	96	99	100	103

2.11 Discussion

The data shows that there are interesting differences in chemical composition between antlers of different geographic regions. It would be premature to make any bold statements on the nature of the differences as we only have two samples and it is impossible to prove the difference has any statistical significance with only two samples. It is interesting to point out the higher representation of Ca and P corresponds with antler T-46, the chewed antler from the CBH (Figure 2.5).

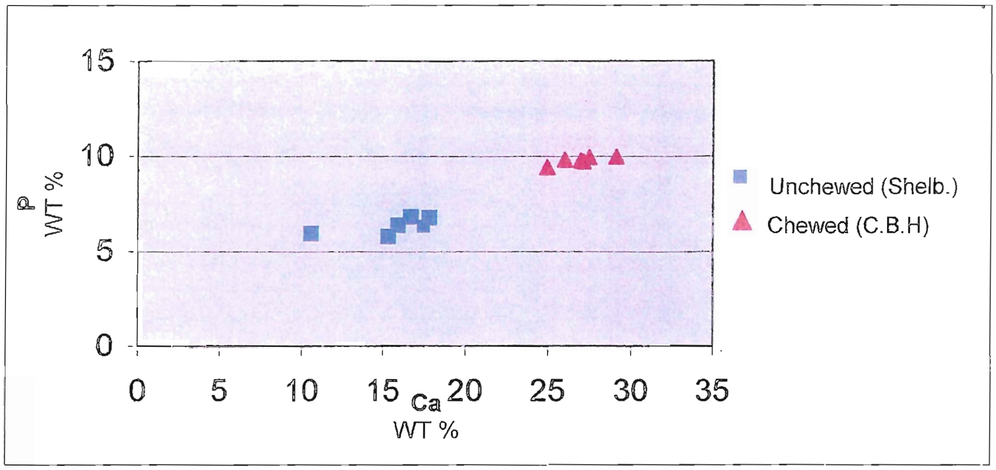


Figure 2.5: Ca/P plot illustrating the differing concentrations between the two antlers. Notice the chewed antler has a higher representation Ca/P.

2.12 Conclusion

The concentrations of Ca and P that correspond with chewed antler from CBH (T-46) are significant, and warrants further investigation because we know that osteophagia is triggered by phosphorous deficiency, and the antler T-46 shows high concentrations of this element.

2.13 Summary of Chapter

Little is known about trace element benefits/requirements in moose. These minerals are obtained from the forage that moose ingest, and the forage will vary geographically as moose are inclined to sample new plants that they encounter.

It is important for moose to have a variety of high quality forage in their diet. Feeding on few plant species will increase the risk of becoming deficient/toxic of trace elements because certain plant species may hyperaccumulate trace elements or may not readily absorb trace elements into the tissue.

Bark stripping occurs when areas support poor winter browse, when food is in short supply in late winter when preferred foods are unavailable or when deep snow cover restricts animals. Bark Stripping is increasingly evident in areas of C.B.H that support high-density moose populations where heavy browsing of preferred vegetation is evident.

Osteophagia occurs in natural conditions and has a distinct geographical distribution that is dependant on the parent rock in which the plants are growing which may be deficient in phosphorous. It may also be influenced by excessive concentrations of Ca, Al or Fe, which can reduce phosphorous availability of to plants.

Thus conclusions, if only suggestive, show a higher representation of Ca and P within the antler of the CBH antler, and warrants further investigation.

Chapter 3: Teeth

3.1 Introduction: Tooth Physiology

Teeth are composed of both inorganic (mineralised) and organic (non-mineralised) substances. There are four main components of the tooth: Enamel, dentin, pulp and cementum. Enamel, dentin and cementum are all mineralised to varying degrees, whilst the pulp is the only non-mineralised component of the tooth.

Enamel is the outside layering of the tooth and encases the crown, and thins down at the base of the crown giving a knife-edge appearance. It varies in thickness, and is approximately 0.25mm-1.5mm thick in moose teeth (Figure 3.1). It is the hardest substance in the body, very brittle, and is 96% mineralised (Melfi, C. 1988), whilst the other 4% is made up of water and organic carbon. Enamel is similar to apatite (Hardness 4 in the Mohs Scale), and belongs to the apatite family. This has been confirmed by x-ray diffraction (Lazarri, E. 1976). More specifically, hydroxyapatite ($Ca_5(PO_4)_3OH$) is the form present within tooth

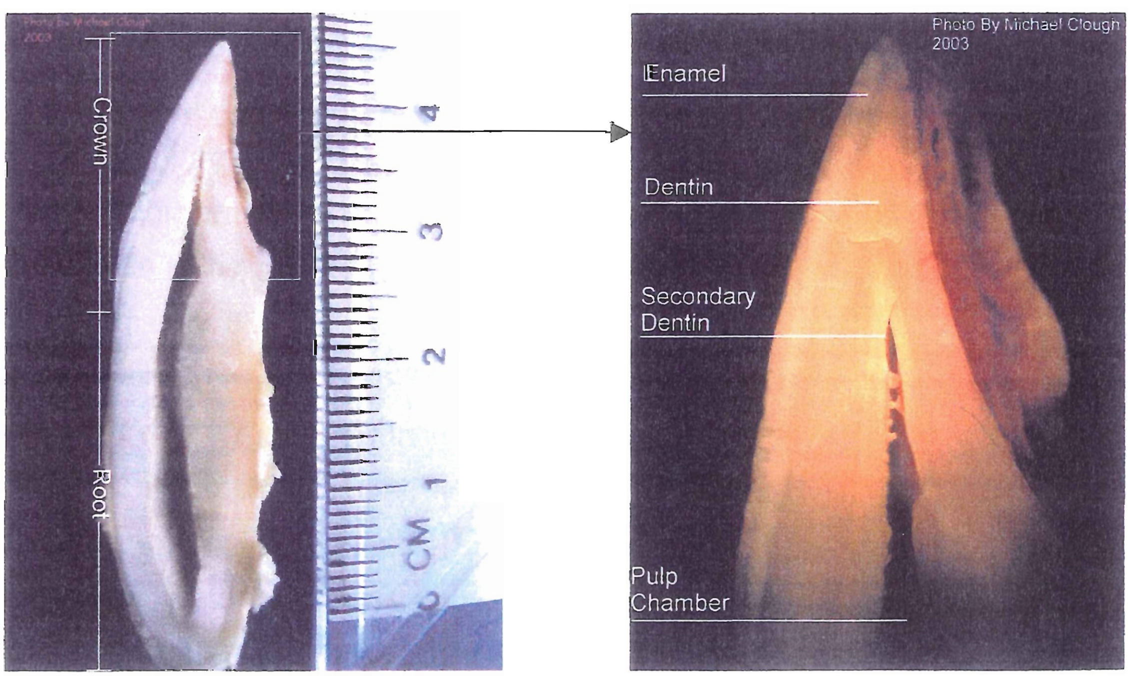


Figure 3.1: (A) Longitudinal section of moose I2 incisor illustrating enamel, dentin and the pulp chamber. (B) Magnified longitudinal section of I2 incisor crown (6X magnification)

enamel. The function of enamel is to form a resistant covering of the tooth, rendering them suitable for mastication (Baskhar S.N., 1991), bearing the force of cropping food (Marieb and Mallatt, 2001). Although tooth enamel is the hardest calcified tissue in the body it is still subject to attrition: the wearing down of the tooth due to friction of use.

Biologic hydroxyapatite is markedly different to pure hydroxyapatite. Differences include inclusions of small amounts of proteinaceous material and trace elements (Curzon and Cutress, 1983). The trace elements present reflect the composition of the tissue environment during tooth formation and the oral environment after tooth eruption (Curzon and Cutress, 1983). Trace elements are incorporated into the apatite crystal lattice during the mineralization period, and also after mineralization preceding eruption elements can diffuse into the tissue (Curzon and Cutress, 1983).

According to Driessens (1982), tooth enamel, preceding eruption, will remain in physico-chemical equilibrium with its oral environment. This is possible due to enamel being semi-permeable, allowing for small ions and molecules to pass through the enamel of the tooth (Driessens, F.C.M. 1982). All present evidence indicates that once any chemical elements are incorporated within the tooth enamel framework, no mineral substances are withdrawn or decreased by any physiologic process within the tooth (Melfi. C. 1988).

Dentin is the second most mineralised component of the tooth. It consists of approximately 68-79% inorganic material, and the remainder is water and organic carbon (Lazarri, E. 1976). It provides the bulk and general form of the tooth (Figure 3.1 & 3.4). Dentin is very similar to bone both physically and chemically, and unlike enamel, which is hard and brittle, dentin is viscoelastic and subject to slight deformation (Baskhar S.N., 1991). In an intact tooth, dentin is not visible due to the crown being covered with enamel.

Cementum is the mineralised dental tissue covering the anatomic root of the tooth (Figure 3.4). It is the least mineralised component of the tooth being only 45-50% mineralised and 50 –55% organic (Lazarri, E. 1976).

Pulp is the only non-mineralised component of the tooth. It is located within the interior of the tooth and occupies the pulp chamber in the crown and the root canal in the root of the tooth (Figure 3.4).

3.2 Mineralization of Enamel

Both deciduous and permanent tooth enamel is mineralised during critical development periods of an animal's lifetime, the second trimester to approximately ten years of age (Goodman and Rose, 1990). There are two stages of mineralization that occur, matrix formation and matrix maturation, although the time interval that takes place between the two appears to be very small (Bhaskar, 1991). Matrix formation involves partial mineralization of the matrix segments, which is in the form of crystalline apatite. While the second stage, maturation, is characterised by the gradual completion of mineralization, which begins at the height of the crown and progresses towards the base of the crown (Figure 3.2) (Bhaskar, 1991). A consequence of this complex calcification pattern is that it is difficult to ascertain the age of the individual at the time of any calcification defects that may occur (Goodman and Rose, 1990), although the cause of defective enamel formation can be generally classified as being a result of systemic, local or genetic in cause. The most common systemic influences are nutritional deficiencies, febrile disease, and certain chemical intoxications (Provenza, 1988).

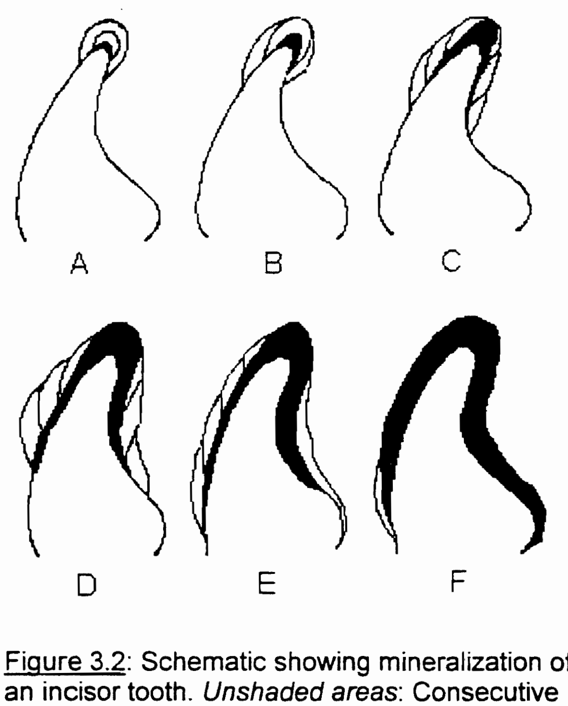


Figure 3.2: Schematic showing mineralization of an incisor tooth. *Unshaded areas*: Consecutive layers of partially mineralised enamel matrix. *Shaded areas:* Advance of final mineralization during maturation (From Crabb HSM: Proc R Soc Med 52:118, 1959: and Crabb HSM and Darling Al: Arch Oral Biol 2:308, 960: *In* Bhaskar, 1991)

3.3 Enamel Structure

Enamel is composed of rods or prisms, rod sheaths, and in some regions a cementing interprismatic substance (Bhaskar, 1991). The rods generally form an orientation that is perpendicular to the external surface of the enamel, except near the incisal edge where the rods are at an angle more directly opposed to masticatory surfaces (Figure 3.3a) (Provenza, 1988). Rods rarely, if ever, form straight lines from dentin to the enamel surface but generally follow a wavy course from the dentin to the enamel surface (Bhaskar, 1991).

Various patterns can also be produced when viewing the enamel prisms under a high-powered microscope by changing the plane of sectioning (Figure 3.3a&b) (Bhaskar, 1991).

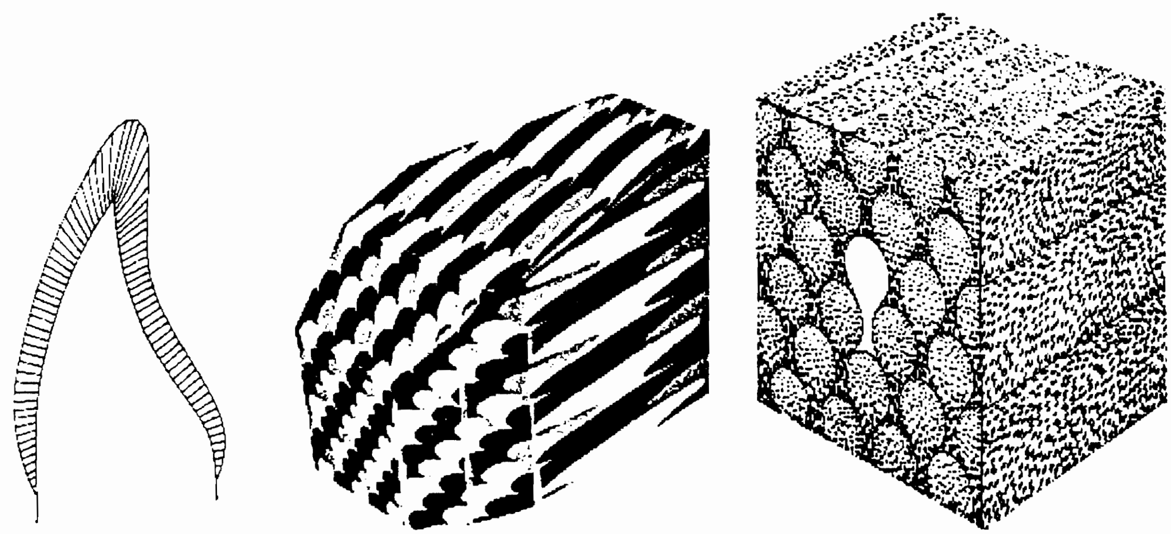


Figure 3.3: (A) Diagrammatic illustration of rod orientation, which is approximately perpendicular to the external surface except near the incisal edge where the rods approach the surface at an angle more directly opposed to masticatory forces (Avery, 1994), 1986)
(B) Various patterns can be produced by changing plane of sectioning (Meckel AH, Griebstein WJ, and Neal RJ: Arch Oral Biol 10:775, 1965; *In* Bhaskar, 1991)
(C) (Griebstein WJ: In Stack MV and Fearhead RW, editors: Tooth enamel, Bristol, 1965, John Wright and Sons, Ltd, p 190; *In* Bhaskar, 1991)

3.4 Dental Caries

The following discussion of dental caries is a summary from Lazarri (1976), unless otherwise noted. Dental Caries, or tooth decay, is a disease of the hard tissue in the teeth whereby the mineral substances of the tooth are dissolved by acid (Melfi, C. 1988), resulting in lesions that penetrate the enamel surface. The process of dental caries progresses to destroy the organic components of the tooth, such as dentin and pulp, which are more susceptible to acid attacks.

Caries will begin as a subsurface demineralisation of the enamel. They will then progress to the dentino-enamel junction (DEJ) (Figure 3.4) and further progress more rapidly through the higher organic containing dentin. Eventually, when left unchecked, caries will involve the pulp and destroy the vitality of the tooth.

The process of dental caries involves salivary bacteria that convert all foods, especially sugars and carbohydrates, into lactic acids. Studies have been done that suggest direct pH measures indicate that carious dissolution takes place in an acid environment. Histological studies demonstrate further that breakdown of the organic matrix occurs only after demineralisation of enamel is well established. Once past the protective enamel layer, lysis of the organic component begins, as acidic ions are free to react with and dissolve the more organic components of the tooth structure.

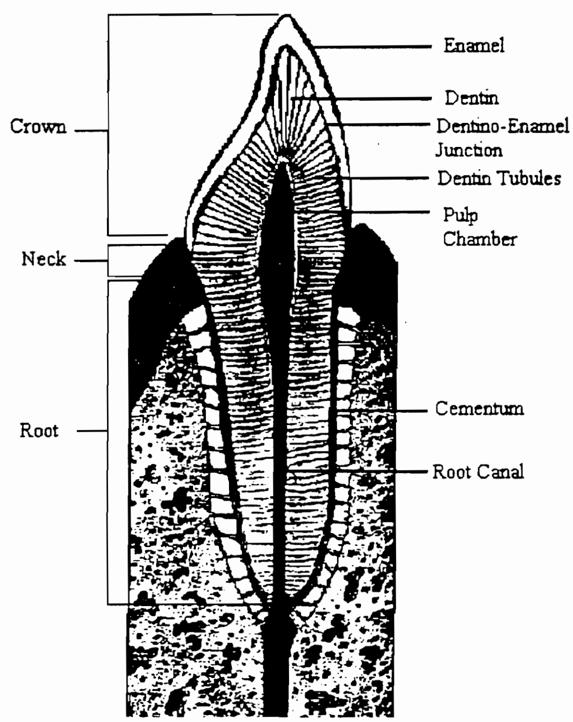


Figure 3.4: Longitudinal Section of canine tooth. (modified from Marieb and Mallat, 2001)

Enamel solubility also plays a major role in susceptibility to caries, and this is a determination of the concentrations of major and trace elements present within the tooth. Newly erupted teeth are generally more susceptible than mature teeth to carious affects. Teeth undergo both physical and chemical alteration following eruption. Maturation and enhanced resistance is generally associated with exposure to the oral environment of the tooth, where mineral-containing saliva will deposit in areas of the tooth. Carbonates will tend to increase enamel solubility while fluorides tend to decrease enamel solubility. With increasing age, there is an increase in the fluoride and a decrease in the Carbonate concentrations of surface enamel.

Carious enamel and dentin contain more water, more organic matter and less mineral content, when measured on a weight basis, than corresponding sound tissue in the same tooth.

Dental caries is not to be confused with fracturing, that is evident within the moose populations, but is intended to illustrate the relationships that are associated with dental disease and trace elements and will be discussed in further detail in chapter 4.

3.5 Trace Elements and Enamel

Trace elements are selectively taken up by enamel and incorporated within the surface enamel over the lifetime of an individual, which reflect the oral environment (Curzon and Cutress, 1983). Within humans, chemical composition of tooth enamel will change over time as individual's age. According to Curzon and Cutress (1983), various factors will influence the occurrence of changing chemistry within the enamel framework, such as normal wear within an individual's life history, food composition, smoking, geographic location, and cultural habits. Curzon and Cutress (1983) feel substantiating studies are still required before conclusions are drawn upon variation by geographic location. A study done by Cutress, (1972, in Curzon and Cutress, 1983) clearly demonstrated that there were higher concentrations of several elements in tooth enamel from one defined geographic source as opposed to another.

3.6 Summary of Chapter

Enamel is the outside layering of a tooth that forms a protective layer, with the primary function of bearing the force of cropping food and mastication. It is markedly similar to apatite, and belongs to the apatite family. More specifically, enamel takes the form hydroxyapatite.

Trace elements present within the tooth enamel are a reflection of the environment during tooth mineralization, and oral environment after tooth eruption. Due to the semi-permeable nature of the enamel framework, trace elements are able to diffuse across the enamel surface, and will remain in physico-chemical equilibrium with the oral environment. Trace elements are selectively taken up by enamel and incorporated into the enamel framework over the lifetime of an individual. Trace element concentrations within enamel may vary according the geographic location of an individual. Trace element concentrations present within the tooth are a determining factor of enamel solubility.

Caries are lesions within teeth, and are not to be confused with fracturing, which is evident in the C.B.H population, and is intended to illustrate associations between dental disease and trace elements.

Defective enamel formation can be generally classified as being a result of systemic, local or genetic in cause. The most common systemic influences are nutritional deficiencies, febrile disease, and certain chemical intoxications.

Chapter 4: Macrofractures and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)

4.1 Introduction

Macrofractures are the type of fractures visible with the naked eye. Macrofractures result in a brown staining of the surface fracture, and indicate, within parts of the tooth, where breakage is imminent, and also where breakage has already occurred (Figure 4.3). Macrofractures are distinguishable from possible breakage due to tooth extraction because the surface where the fracturing has occurred is usually rounded out, indicating that fracturing occurred long before the death of the moose (Figure 4.3).

Inductively Coupled Mass Spectrometry (ICP –MS) was the analytical tool utilised for measuring the trace element concentration of the enamel. This technique was favoured due to it being a powerful tool for measuring a variety of trace elements at very low (ppm) detection limits.

4.2 Tooth Collection and Storage

Teeth samples were obtained from the 2001-hunting season. Each year during the annual moose hunt the Nova Scotia Department of Natural Resources (NSDNR), Wildlife Division, require that hunters hand in the lower mandible with teeth intact for age determination by cementum age analysis. Prior to processing, the teeth are kept in a frozen storage locker. It is important to keep the teeth in a cool dry place, preferably in paper envelopes so that the teeth will dry without rotting. In sealed plastic envelopes, there will be decomposition of soft tissues associated with the teeth, creating an undesirable nuisance factor for technicians who handle the teeth later on (Matson's Laboratory, LLC, 2004). Jaws were also categorized for ease of study. Individual moose were assigned with the letter 'M', followed with three digits (eg; M001).

4.3 Tooth Extraction

The jaws were soaked in a hot distilled water bath at 70 –90 degrees centigrade for 4-6 hours as stipulated by Matson's Laboratory (2004). The attachment between incisor and mandible of the ungulate is largely soft tissue, so this was severed by cutting it with a sharp knife on either side of the tooth. After the cut was made, the tooth was loosened by gently twisting and rocking it before pulling it out with an extractor (Matson's Laboratory, LLC, 2004). Care must be taken so as not to inflict damage to the tooth.

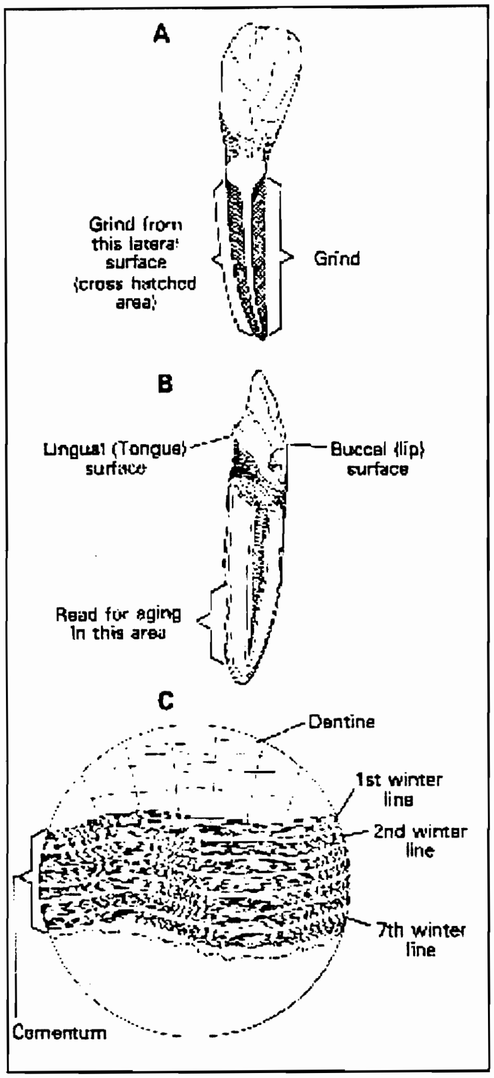


Figure 4.1: Frontal (A) view of a moose tooth, indicating surface to be ground away for cementum analysis; lateral (B) view of a ground down tooth; and (C) 30-power magnification of a crossed section tooth of a 7-year moose killed in autumn. (Illustrations by Celia Carl Anderson; redrawn from original by Dave Harkness, Alaska Dept. of Fish and Game, in Franzmann and Schwartz, 1997).

For this study, the I1 and I2 incisors were extracted. The I1 incisor was sent for cementum annuli dating to the Matson's Laboratory, LLC (2004). The I2 incisor was used for ICP-MS analysis. Overall, 56 individual I1 incisors were sent away for cementum annuli analysis, whilst the 56 I2 incisors were kept and documented.

4.4 Cementum Analysis

The basis for cementum aging is similar to the processes that occur within trees. Annular rings are formed when physical pressure is exerted on the teeth during foraging, which stimulates development of new protective layers of cementum around the roots (Franzmann and Schwartz, 1997). Layers formed in spring and summer are lightly stained, and are thicker and denser than the darkly stained "annulus", or ring formed during the winter months (Figure 4.1) (Franzmann and Schwartz, 1997; Matson's Lab, 2004).

4.5 Tooth Categorization and Selection

Nette and Power (unpublished, 1999) devised a simple classification system for determining the state of moose teeth in terms of macrofracture present. Based on previous work done by Smith (1992), they categorized the teeth based on three levels of damage, rather than the 5 levels used by Smith (1992). 1) Indicates none/slight damage (<30% of tooth material missing from the cutting surface), 2) Indicates moderate damage (30-60% of tooth material missing from the cutting surface). Finally 3) indicates severe damage (>60% of tooth material missing from the cutting surface).

Figure 4.2 illustrates a healthy set of incisor teeth, where there is no evidence of macrofractures present. Notice there are eight incisors in total, all given a prefix to identify where from the mandible they originate. Figure 4.3 shows a set of incisors with fracturing of various degrees present. Brown stains running perpendicular to the enamel surface are evidence of initial fracturing. The stained fractures appear to weaken the enamel structure, eventually breaking off. After breakage has occurred, the tooth surface will become polished and stained brown again (Figure 4.3). This is an important characteristic of the fracturing because it implies that the moose was living for a period of time after breakage occurred. When fresh breaks occur, the staining and rounded surface will not be present and can imply that breakage occurred just prior to the death of the animal, or even that it occurred after death.

Of the 56 teeth collected and documented, 46 were from the CBH (33 North of the National Park, 13 South of the National park), 5 from Shelburne County (including areas of the Tobeatic Wilderness area), 2 from Baddeck (Victoria County), 1 from coxheath (Cape Breton), 1 from Parrsboro (Cumberland County) and 1 from Sheet Harbour (Halifax County). Table 4.1 shows a list of samples and categorization. From the list, teeth 25 were selected for ICP-MS analysis.

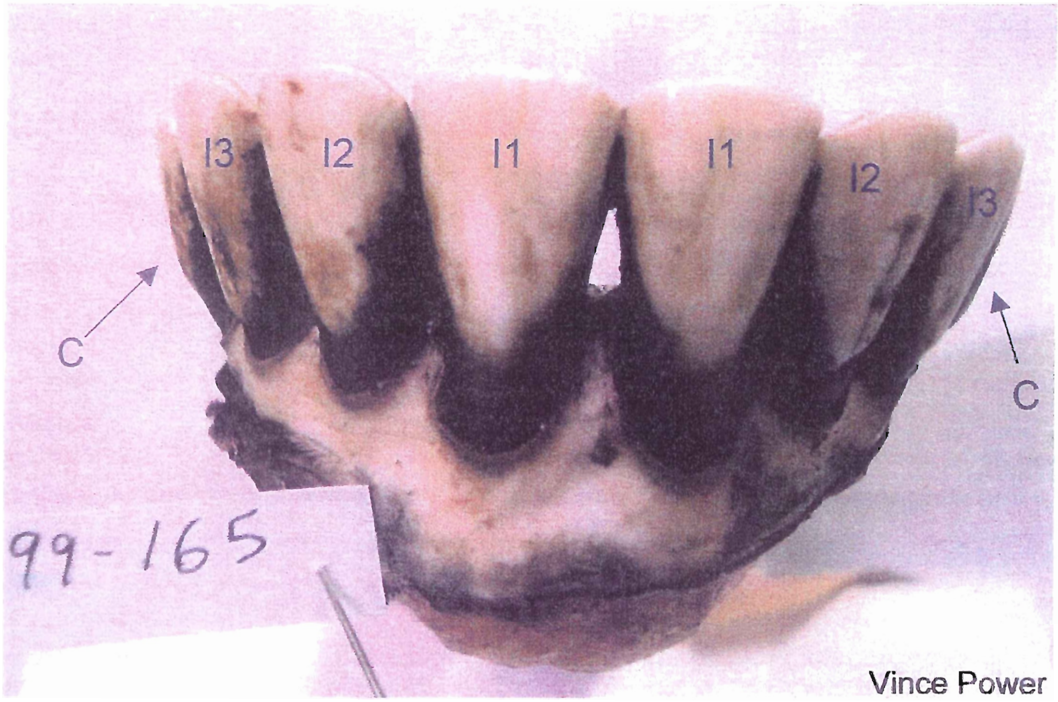


Figure 4.2: example of a healthy set of moose teeth, with no evidence of fracturing, from the control area. Notice there are 8 teeth in total (6 incisors, 2 canines), with identifiers I1-I3 and C (Also given a Prefix Right or Left to determine which side of the jaw is being referred to. This is from the perspective of the moose) (Photo by Vince Power, 2002).

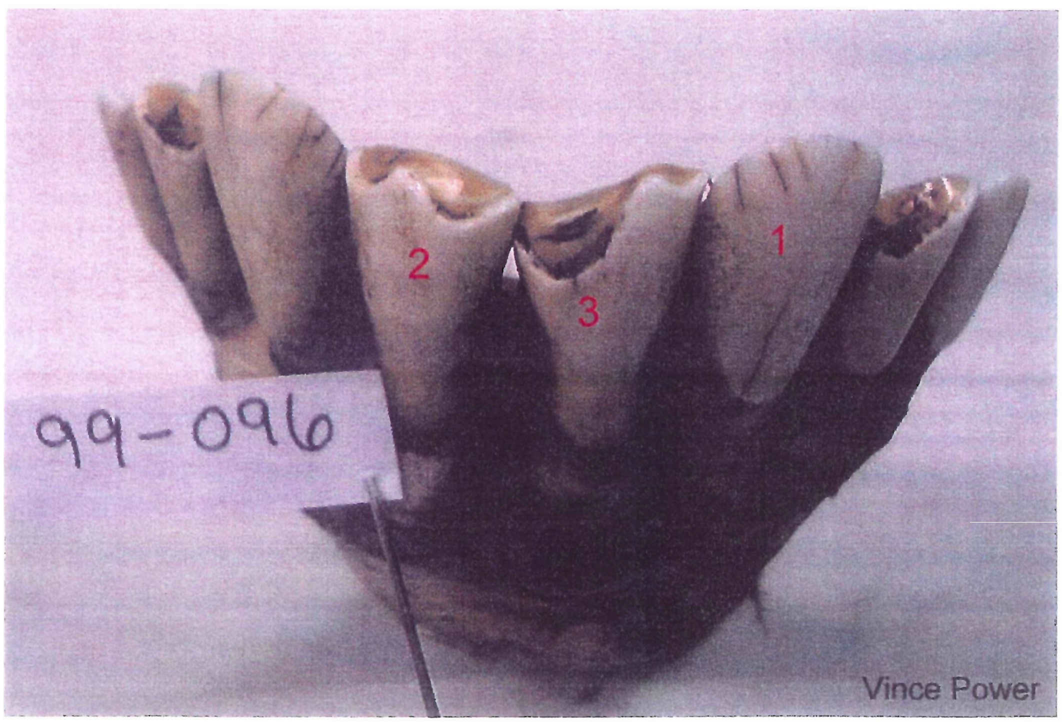


Figure 4.3: Lower mandible from a C.B.H moose with varying degrees of fracturing present. Note the brown staining and polished surfaces of the fractured teeth, indicating fracturing occurred some time before the death of the animal (Photo by Vince Power, 2002).

Table 4.1: Categorization of moose teeth from 2001. C.B.H samples obtained from hunting season, others are either live extraction or from road kills

Sample Number	Other Id Number	Location	Age	SEX 1=MALE 2=FEMALE	TOOTH DAMAGE none/slight= 1 moderate= 2 severe= 3	NOTES
m001	7	Cape Breton north	6.5	2	3	
m002	10	Cape Breton north	3.5	1	3	
m003	13	Cape Breton north	3.5	1	1	lots of fine cracks
m004	17	Cape Breton north	3.5	1	1	split vertically-fine cracks
m005	22	Cape Breton South	3.5	1	1	plaque
m006	30	Cape Breton South	3.5	1	1	
m007	37	Cape Breton north	2.5	2	3	mostly missing(breach looks fresh)
m008	38	Cape Breton South	4.5	2	1	Split vertically- lots of cracks
m009	40	Cape Breton north	6.5	2	2-3	
m010	49	Cape Breton north	2.5	2	1	
m011	50	Cape Breton South	2.5	2	1	
m012	51	Cape Breton north	8.5	1	3	
m013	53	Cape Breton north	3.5	2	3	v.black (plaque)
m014	56	Cape Breton north	8.5	2	3	
m015	72	Cape Breton north	3.5	2	1	vertically split
m016	75	Cape Breton South	4.5	2	1	vertically split
m017	77	Cape Breton north	5.5	2	2	
m018	81	Cape Breton South	3.5	2	1	
m019	84	Cape Breton north	unk	1	1	nice-split vertically
m020	87	Cape Breton north	6.5	2	2	
m021	88	Cape Breton north	3.5	1	3	
m022	91	Cape Breton north	4.5	1	2-3	
m023	92	Cape Breton north	2.5	1	3	
m024	96	Cape Breton South	11.5	1	2-3	
m025	97	Cape Breton north	7.5	2	3	some damage(looks fresh)Vert.splt
m026	100	Cape Breton South	3.5	1	1-2	old looking damage (Black)
m027	106	Cape Breton South	7.5	1	3	
m028	114	Cape Breton north	6.5	2	2-3	
m029	119	Cape Breton north	3.5	1	1	
m030	124	Cape Breton north	8.5	2	2	
m031	127	Cape Breton north	7.5	1	3	
m032	129	Cape Breton north	4.5	2	1	lots of cracks
m033	134	Cape Breton South	3.5	1	1	lots of cracks
m034	149	Cape Breton north	unk	1	1	
m035	154	Cape Breton north	2.5	1	1-2	
m036	155	Cape Breton north	3.5	1	3	
m037	157	Cape Breton South	7.5	1	3	
m038	164	Cape Breton north	1.5	1	1	
m039	166	Cape Breton north	2.5	1	3	Break looks fresh (vert. Split)
m040	179	Cape Breton north	3.5	1	1	
m041	182	Cape Breton South	3.5	2	2	vertically split
m042	184	Cape Breton South	4.5	2	3	
m043	185	Cape Breton north	3.5	2	1	cracks
m044	186	Cape Breton north	3.5	1	2-3	
m045	197	Cape Breton north	10.5	1	3	
m046	198	Cape Breton north	unk	2	3	
m047	211780	Coxheath Cape Breton	unk	1	3	tiny piece fell off
m048	205758	Baddeck Victoria	adult	2	1-2	brown
m049	205613	Baddeck Victoria	adult	1	1	
m050	201169	Sheet Harbour Halifax	unk	2	1	
m051	52124	Shelburne	2.5	2	1	nice
m052	52124	Parrsboro Cumberland	2.5	2	1	slight v.split
m053	moose8	Tobeatic	live (7)	2	1	nice
m054	moose10	Tobeatic	live (11)	1	1	nice
m055	moose14	Tobeatic	live	2	1	V.nice
m056	moose15	Tobeatic	live	2	1	V.nice

Shelburne County was selected as the control area based on the assumption it is a healthy population, having no documentation of the problems that are plaguing the C.B.H moose. Four teeth from Shelburne County were selected, and for statistical purposes, the single tooth from Parrsborro was included for analysis for reasons owing to the displacement of M054. Ten teeth were selected from North of the Park and 10 from South of the Park. Within both samples of 10, there were 4 teeth with breakage values of 1, and 3 each with breakage values of 2 and 3, giving a total of 10 teeth in each sample (Table 4.2)

4.6 Inductively Coupled Plasma Mass-Spectrometry (ICP-MS)

ICP-MS analysis is a powerful technique for multi-elemental material. It is particularly useful for analysing those elements that occur in low concentrations, such as the rare earths (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and LU) plus Y, the high field strength elements (Zr, Nb, Hf, Ta, Th, and U), and large ion-lithophile elements (Rb, Sr, Cs, and Ba). (GEOlabs, 2003)

In a typical application, the sample of interest is completely dissolved in acid to a solution suitable for spraying into flowing argon that is passed into a torch, which is inductively heated to approximately 10,000^{o}C (West Coast Analytical Service, 2004). At this temperature, everything is atomized and ionized, forming plasma which provides a rich source of both excited and ionized atoms (West Coast Analytical Service, 2004). By acquiring the mass spectrum of the plasma, data can be obtained for almost the entire periodic table in just minutes (West Coast Analytical Service, 2004), giving detection limits from the low parts-per-trillion (ppt) level, up to hundreds of parts-per-million (ppm) (GEOlabs, 2003).

Table 4.2: Teeth chosen for geochemical analysis

Healthy	AGE	North of the Park	AGE	South of the Park	AGE	Breakage (CBH)
M051	2.5	M003	3.5	M005	3.5	1
M052	2.5	M010	2.5	M006	3.5	1
M053	?	M023	2.5	M016	4.5	1
M055	?	M038	1.5	M018	3.5	1
M056	?	M017	5.5	M008	4.5	2
		M022	4.5	M011	2.5	2
		M030	8.5	M041	3.5	2
		M001	6.5	M027	7.5	3
		M009	6.5	M037	7.5	3
		M012	8.5	M042	4.5	3

4.7 Methods: Sample Preparation

Great care has to be taken when preparing the samples. Because of its high degree of mineralization, enamel is the preferred substance for analysis as we are analysing for trace elements that potentially occur in extremely low concentrations within animal bones and tissue.

Moose teeth have a layering of enamel surrounding the dentin that is approximately 0.25-1.5mm (Figure 3.1b), so amounts were limiting and care had to be taken so that we could utilize as much of the enamel as possible to make up the required amounts for ICP-MS analysis, which requires a 2.0g sample.

The preparation of the enamel to a fine powder, of 200-mesh size as required by the laboratory for ICP-MS analysis, was preformed in 5 steps:

Step 1: Separation of the root from the crown.

The crown was separated from the root using a Buhler Isomet Low speed saw with a diamond tip blade in the Fission Tracks Lab at Dalhousie University.

Step 2: Crushing of teeth with Percussion cutter

Individual crowns were placed into the percussion cutter and carefully pulverized into fragments. At this point we did not want to pulverize to powder. If it was crushed to a complete powder, we could not distinguish the enamel from the other components of the tooth. It was found that by placing the enamel surface parallel with the crusher and gently crushing the tooth, enamel fragments were more likely to break off as larger fragments, rather than tiny shards.

Step 3: Recovery of enamel under binocular microscope

The fragments were removed from the percussion cutter and placed under the binocular microscope and the enamel pieces were carefully selected and extracted using a fine tipped paintbrush and then placed into an appropriately labelled vial. Enamel was distinguishable under the binocular microscope, owing to its bright white colour compared to dentin and pulp that appeared as a pale yellow colour under the microscope. Some fragments that contained enamel and small fractions of dentin could be separated using a sharp blade.

Step 2 and 3 was repeated several times until sufficient quantities of enamel had been extracted. With practice, it becomes evident which pieces are more likely to yield good enamel fragments. By selecting these fragments and placing them back into the percussion cutter one can increase the enamel concentration and reduce the dentine and pulp waste in the pile when observing under the binocular microscope improving the efficiency of enamel extraction.

Step 4: Reducing Enamel to Fine Grain Powder

The enamel was then reduced to powder using an agate mortal and pestle. An ultrasound bath filled with distilled water was used to clean the mortal and pestle prior to every sample that was prepared to decrease the chances of cross contamination between the samples. Distilled water is important because we are analysing for trace elements, and it is possible for such elements to be found in the drinking/tap water. Ethanol was used to lubricate the enamel and aided in the reduction to a powder, and prevented fragments from scattering. Once there were no large fragments left, the pestle was rinsed with ethanol into the mortal, then the mortal was emptied and the remaining enamel rinsed with ethanol into a drying dish and left to dry at room temperature. Cleaning in warm soapy water, and then rinsing with distilled water prepared the drying dishes. The enamel was left to air dry.

Step 5: Recovery of enamel powder

Recovering the powder from the drying dishes was done with a fine brittle paintbrush. The use of a fine bristle brush over a large bristle brush was preferred as it allowed for more control of recovering the sample as the large bristled brush causes the enamel powder to scatter. The powder was carefully brushed onto a sheet of weighing paper 8cm * 8cm that was placed on top of a larger sheet of drying paper 15cm * 15cm in case any material was scattered. New sheets of weighing paper were used for each sample to prevent cross contamination. The enamel powder was then placed into an appropriately labelled vial ready for analysis. The paintbrush was cleaned between each sample by blowing and wiping in paper towel, and more thoroughly cleaned between the sample groups by washing with warm soapy water and rinsing with distilled water and being allowed to air dry. It was discovered that recovery of the enamel powder was easiest immediately after drying, rather than leaving the samples overnight where the enamel was able to stick harder to the drying dish and recovery was much more labour intensive, thus creating more chance of the sample scattering.

For control of analysis, samples M017 and M032 are controls for the North and samples M008 and M020 are controls for the South.

4.8 <u>Results</u>

Appendix A shows the raw data of results for ICP-MS analysis for all 25 samples, and the 52 elements that were analysed. From this data the results were divided into 3 individual populations; those North of the Park; those South of the Park; and the control population. The North and South populations were further divided into three populations within the overall populations in terms of tooth breakage based on the classification scheme devised by Nette and Power (unpublished, 1999) to determine if there were any significant differences in mean values between the various levels of fracturing.

Statistical analysis using one-way ANOVA of variance was used to compare variations between the populations, and also the variations within the population samples. The specified hypothesis for the problems were:

Null: *all means are equal within/between the populations.*

Alternative: *not all means are equal.*

All output was compared with Tables of *F* critical values.

Initially, the one sample that originated from the Parrsboro area (M052) was included within the analysis of data, with full statistical analysis using ANOVA (Appendix B). However, following advice by Zentilli and Nette (Personal Communication, 2004) ANOVA was conducted without M052 to see if there were any differences to the outcome of results (Appendix C). There was a clear shift with the mean and Confidence Bands between the two different statistical analyses for numerous elements. Therefore, from this point forward any reference to the control population will include only those from Shelburne County.

By comparing mean values of concentration based on the different breakage rates using ANOVA, it was possible to see varying degrees of a marked increase/decrease in the mean across the different levels of breakage. Appendix D (North of the Park) and Appendix E (South of the Park) illustrate these trends. After performing this analysis, it was evident that there may be correlations between elemental concentration and breakage score. Therefore, a complete analysis of correlating the breakage score against elemental concentration was performed for North of the Park (Appendix F) and South of the Park (Appendix G). Appendix F and Appendix G also show the 2 control samples used within the populations, with associated error (at 95% Confidence of the Standard Error). Error varied between elements, and was quite large for some, yet quite small for others. Refer to the Appendix G and Appendix F to see how the error varied.

Table 4.3: Minor constituents of enamel for North of the Park. Numbers indicate: mean ~ 1 Standard Error with 95% Confidence.

Elements	*Symbol*	*Microgram/ Gram (PPM)*	*Elements*	*Symbol*	*Microgram/ Gram (PPM)*
Aluminium	Al	*49.1 ~ 28.03*	Molybdenum	Mo	*0.0503 ~ 0.019*
Antimony	Sb	*0.0393 ~ 0.0255*	Niobium	Nb	*0.0226 ~ 0.0179*
Arsenic	As	*5.080 ~ 0.788*	Rubidium	Rb	*0.4634 ~ 0.1103*
Barium	Ba	*125.85 ~ 15.99*	Selenium	Se	*1.354 ~ 0.098*
Beryllium	Be	*0.01155 ~ 0.00559*	Silicon	Si	*185.1 ~ 84.87*
Bismuth	Bi	*0.01673 ~ 0.00398*	Silver	Ag	*0.0793 ~ 0.0515*
Cadmium	Cd	*0.1615 ~ 0.1115*	Strontium	Sr	*269.8 ~ 22.34*
Calcium	Ca	*34.81 ~ 1.52*	Tantalum	Ta	*0.0011 ~ 0.00059*
Cesium	Cs	*0.00327 ~ 0.00047*	Thallium	Tl	*0.00711 ~ 0.00167*
Chromium	Cr	*0.0951 ~ 0.0659*	Tin	Sn	*0.0633 ~ 0.0259*
Cobalt	Co	*0*	Titanium	Ti	*96.55 ~ 15.62*
Copper	Cu	*22.37 ~ 8.134*	Thorium	Th	*0.0018 ~ 0.00071*
Gallium	Ga	*0.2251 ~ 0.015*	Tungsten	W	*8.67 ~ 4.86*
Hafnium	Hf	*0.01535 ~ 0.01382*	Uranium	U	*0.00216 ~ 0.00037*
Iron	Fe	*107.9 ~ 30.38*	Vanadium	V	*0.3918 ~ 0.158*
Lead	Pb	*0.7231 ~ 0.0827*	Yttrium	Y	*0.0493 ~ 0.0057*
Lithium	Li	*0.980 ~ 0.423*	Zinc	Zn	*54.92 ~ 8.62*
Magnesium	Mg	*3215 ~ 392*	Zirconium	Zr	*0.674 ~ 0.694*
Manganese	Mn	*54 ~ 20.97*	Rare Earths	REE	*0.1663 ~ 0.039*

Table 4.4: Minor constituents of enamel for South of the Park. Numbers indicate: mean ~ 1 Standard Error with 95% Confidence.

Elements	*Symbol*	*Microgram/ Gram (PPM)*	*Elements*	*Symbol*	*Microgram/ Gram (PPM)*
Aluminium	Al	*81.5 ~ 63.11*	Molybdenum	Mo	*0.06 ~ 0.043*
Antimony	Sb	*0.0147 ~ 0.0067*	Niobium	Nb	*0.0176 ~ 0.0042*
Arsenic	As	*4.603 ~ 0.292*	Rubidium	Rb	*0.7507 ~ 0.133*
Barium	Ba	*125.5 ~ 30.97*	Selenium	Se	*1.3435 ~ 0.0637*
Beryllium	Be	*0.0176 ~ 0.0052*	Silicon	Si	*161.4 ~ 59.98*
Bismuth	Bi	*0.01312 ~ 0.0099*	Silver	Ag	*0.0275 ~ 0.0112*
Cadmium	Cd	*0.0617 ~ 0.0198*	Strontium	Sr	*266.9 ~ 46.26*
Calcium	Ca	*34.725 ~ 0.76*	Tantalum	Ta	*0.0019 ~ 0.0012*
Cesium	Cs	*0.0067 ~ 0.0037*	Thallium	Tl	*0.0081 ~ 0.0022*
Chromium	Cr	*0.0687 ~ 0.072*	Tin	Sn	*0.105 ~ 0.063*
Cobalt	Co	*0.0348 ~ 0.058*	Titanium	Ti	*80.57 ~ 7.8*
Copper	Cu	*12.46 ~ 5.037*	Thorium	Th	*0.00585 ~ 0.0039*
Gallium	Ga	*0.1893 ~ 0.0196*	Tungsten	W	*6.56 ~ 4.61*
Hafnium	Hf	*0.00599 ~ 0.0048*	Uranium	U	*0.00464 ~ 0.0029*
Iron	Fe	*175.9 ~ 162.88*	Vanadium	V	*0.3818 ~ 0.0894*
Lead	Pb	*0.888 ~ 0.288*	Yttrium	Y	*0.0746 ~ 0.033*
Lithium	Li	*1.076 ~ 0.535*	Zinc	Zn	*54.51 ~ 9.98*
Magnesium	Mg	*3644 ~ 442.96*	Zirconium	Zr	*0.239 ~ 0.25*
Manganese	Mn	*59.6 ~ 28.8*	Rare Earths	REE	*0.435 ~ 0.396*

Table 4.5 Minor constituents of enamel for the Control Population. Numbers indicate: mean ~ 1 Standard Error with 95% Confidence.

Elements	*Symbol*	*Microgram/ Gram (PPM)*	*Elements*	*Symbol*	*Microgram/ Gram (PPM)*
Aluminium	Al	*73.88 ~ 13.07*	Molybdenum	Mo	*0.05318 ~ 0.01824*
Antimony	Sb	*0.2455 ~ 0.0133*	Niobium	Nb	*0.02042 ~ 0.00274*
Arsenic	As	*5.41 ~ 1.033*	Rubidium	Rb	*0.7816 ~ 0.1513*
Barium	Ba	*201.4 ~ 42.14*	Selenium	Se	*1.406 ~ 0.055*
Beryllium	Be	*0.02726 ~ 0.01589*	Silicon	Si	*149.4 ~ 14.99*
Bismuth	Bi	*0.02406 ~ 0.0851*	Silver	Ag	*0.05818 ~ 0.0195*
Cadmium	Cd	*0.3762 ~ 0.1834*	Strontium	Sr	*468.2 ~ 103.88*
Calcium	Ca	*34.66 ~ 1.55 (wt %)*	Tantalum	Ta	*0.00069 ~ 0.00041*
Cesium	Cs	*0.00753 ~ 0.00167*	Thallium	Tl	*0.00799 ~ 0.00166*
Chromium	Cr	*0.1651 ~ 0.102*	Tin	Sn	*0.42 ~ 0.24*
Cobalt	Co	*0.869 ~ 0.480*	Titanium	Ti	*87.12 ~ 10.82*
Copper	Cu	*22.66 ~ 4.66*	Thorium	Th	*0.00948 ~ 0.00484*
Gallium	Ga	*0.1676 ~ 0.0133*	Tungsten	W	*3.69 ~ 2.37*
Hafnium	Hf	*0.0146 ~ 0.0225*	Uranium	U	*0.00531 ~ 0.00145*
Iron	Fe	*318.4 ~ 169.34*	Vanadium	V	*0.5734 ~ 0.156*
Lead	Pb	*2.15 ~ 0.856*	Yttrium	Y	*0.1307 ~ 0.03*
Lithium	Li	*1.066 ~ 0.429*	Zinc	Zn	*63.76 ~ 8.68*
Magnesium	Mg	*2912 ~ 311.64*	Zirconium	Zr	*0.0567 ~ 0.028*
Manganese	Mn	*38.4 ~ 18.93*	Rare Earths	REE	*0.909 ~ 0.629*

Two outliers from North of the Park were eliminated from the analysis. M009 was discarded from the Fe analysis, having a value of 1600ppm (averaging 15 times higher in concentration than all other samples for Fe), and M022 was eliminated from the Li analysis, having a value of 17.3ppm (averaging 17 times higher in concentration than all other samples analysis for Li). Three outliers were eliminated from the analysis for South of the Park. M011 was discarded from both Cd and Fe (averaging 110 and 10 times higher in concentration than all other samples within the analysis respectively), and M018 was discarded from Ag (averaging 25 times higher in concentration than all other samples in the analysis).

Basic statistics were calculated for all the sample populations and tabulated for ease of reference. For all 3 populations, the Rare Earth Elements

(REE) was summed, and the mean and Standard Error with 95% confidence was calculated. Table 4.3 shows the mean concentration of elements for the entire population North of the Park with associated Standard Error at the 95% confidence level. Table 4.4 shows the mean concentration of elements for the entire population South of the Park, with associated Standard Error at the 95% Confidence level. And Finally, Table 4.5 shows the mean concentration of elements for the entire population of the control area, with associated Standard Error at the 95% Confidence level.

For ease of discussion, discussion of results will be set out in three sections. The first section will discuss significant differences between elemental concentration for both the population North of the Park and population South of the Park against the control population. The second section will discuss significant differences between the population North of the Park against the control population and significant differences between the population South of the Park against the control population. And finally, the third section will discuss any significant correlations that may be apparent between elemental concentration and breakage score for the population in the C.B.H.

4.9 Healthy Vs C.B.H (North and South of the Park)

Within the CBH, results show that 5 elements, Barium, Lead, Strontium, Cobalt and Tin differ significantly in the C.B.H moose compared to that of the control population, all showing depleted levels. The following discussions will give individual attention to each of the above-mentioned elements, followed by bringing all the information together and drawing conclusions upon the discussions collectively.

4.9.1 Discussion of Barium (Ba)

Barium shows significant depletion in both C.B.H populations (Figure 4.4). Barium does occur widely in soils, plants and animal tissues in highly variable concentrations, although little is retained within the tissues of animals because it is poorly absorbed from most diets (Underwood, 1971). According to Underwood (1971) and Frieden (1984), evidence to suggest that Ba performs any essential biological functions in plants or animals has not been confirmed (or denied), although it has been shown to act as a growth stimulant in plants. Rygh (1949; in Frieden 1984) claimed that the omission of Ba from the diet resulted in depressed growth and reduced calcification of bones and teeth in rats and Guinea Pigs.

The role of Barium in tooth disease is unclear at best. According to Curzon and Cutress (1983), research on Ba and dental disease has been very limited, and is insufficient for any conclusions of any possible role for the element in dental disease. Curzon and Cutress (1983) refer to two studies undertaken to determine the role of Ba in dental disease in humans. One study carried out by Schamschula et al. (1978, in Curzon and Cutress, 1983) identified a positive correlation of Ba with dental caries in surface enamel of human samples taken from Papua-New Guinea.

A similar study carried out by Curzon and Losee (1977, in Curzon and Cutress, 1983) indicated significantly higher Ba concentrations in the enamel of humans from a population sample taken from New England who displayed a high incidence of Caries, compared to a population sample taken from South Carolina who displayed a low incidence of caries.

Shaw and Griffiths (1961, in Curzon and Cutress, 1983) demonstrated Ba as having minor influences on caries prevalence.

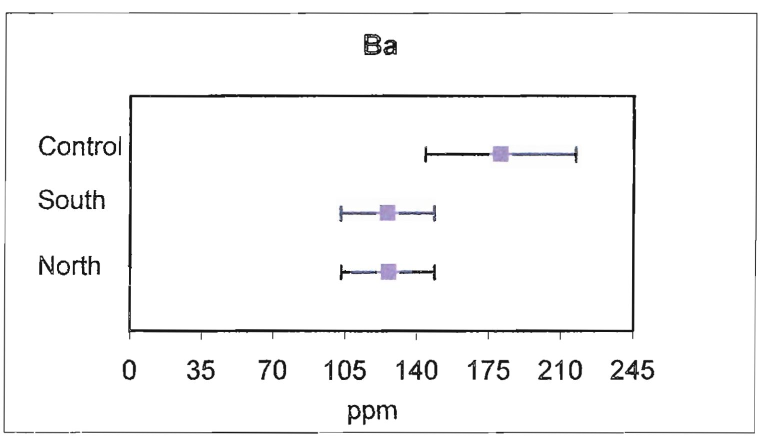


Figure 4.4: ANOVA results for Ba. Individual 95% Confidence Intervals based on pooled standard deviation.

4.9.2 Discussion of Lead (Pb)

Lead shows significant depletion within the C.B.H populations, compared to the control (Figure 4.5). Lead occurs naturally and widely in soils and plants, plants that grow in areas of low lead concentrations rarely contain more than a few ppm (Underwood, 1971). Lead levels within animals, plants and the environment are not equivalent to those that prevailed during the creation and evolution of physiological responses, they represent levels that have been elevated due to anthropogenic activities involving the injection of millions of tons of lead into the environment (Underwood, 1971).

Excessive lead toxicity has been well documented over the years, with symptoms that include anaemia, and neuropathy or encephalopathy (Underwood, 1971). Yet, the possibility that lead in low concentrations performing some essential biochemical function cannot be excluded. Experiments have been conducted that show Pb depletion may result in reduced retention of Fe in animal tissue, and Frieden (1984) gives a full account of the experiments, which provides an in depth discussion. Fe deficiency results in anemia, or reduced haemoglobin.

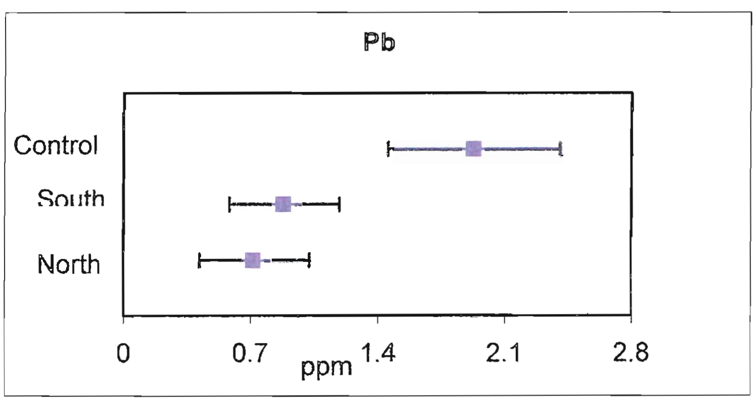


Figure 4.5: ANOVA results for Pb. Individual 95% Confidence Intervals based on pooled standard deviation.

In dental disease, there have been no clear conclusions drawn upon the influence lead may have. An extensive study conducted by Curzon (1977, in Curzon and Cutress, 1983) illustrated that there was a trend toward higher enamel Pb with lower prevalence of caries in human teeth.

Anda (1976, in Curzon and Cutress, 1983) on the other hand found that increased Pb level in teeth was found to be associated with increased industrial exposure and higher caries incidence. Proud (1976, in Curzon and Cutress, 1983) and Moses et al (1976, in Curzon and Cutress, 1983) both illustrated a negative trend.

Studies conducted on animals have also produced mixed results. Wisotzky and Hein (1958, in Curzon and Cutress, 1983) observed Pb to be a caries-promoting agent in male, but not female hamsters. Lazansky (1947, in Curzon and Cutress, 1983) demonstrated, according to a preliminary report, that by brushing the teeth of hamsters with a mascara brush charged with Pb-fluoride solution three times a week that there was a three quarter reduction of caries affected molars.

4.9.3 Discussion of Strontium (Sr)

Strontium is significantly depleted in the C.B.H moose populations compared to the control area (Figure 4.6). Strontium in animal tissue is a reflection of the concentrations found within drinking water supplies, and there is evidence that suggests it will increase with age, and that it varies with geographic regions (Curzon and Cutress, 1983).

Plants will readily absorb Sr into their tissues and it has been claimed to be a plant growth stimulant (Underwood, 1971), but has not been shown to be essential for plant or animal functions.

Calcium and strontium have a strong interaction, as the distribution of Sr within minerals, rocks, sediments and water is affected by the presence of calcium (Fairbridge, 1972). It is generally found in greatest amounts in calcium rich minerals, and to a lesser extent in potassium rich minerals (Fairbridge, 1972).

Dental studies within humans have been conducted that suggest a negative association between Sr and caries - the prevalence of caries being decreased as environmental Sr increases (Curzon and Cutress, 1983). Studies relating trace elements to dental disease carried out by Curzon and Losee, (1977, 1978, from Curzon and Cutress, 1983) selected geographic areas with high and low caries. Their results showed higher Sr concentrations in enamel from the area of low caries than the high caries area, and also higher enamel Sr in low caries individuals within each area.

Rygh (1949, from Curzon and Cutress, 1983) studied the effects of a number of trace elements on growth and health of rats. He found that a reduction of Sr levels produced poorer calcification and dental decay in the teeth of the rats. Studies done since Rygh's (1949, in Curzon and Cutress, 1983) have generally indicated that increased Sr may lead to a decrease in caries in rodents (Curzon and Cutress, 1983).

Because of its close similarity to Ca with regard to physical and chemical properties, it is theoretically possible that Sr can replace Ca in hydroxyapatite (Curzon and Cutress, 1983). Dedhiya (1974, from Curzon and Cutress, 1983)

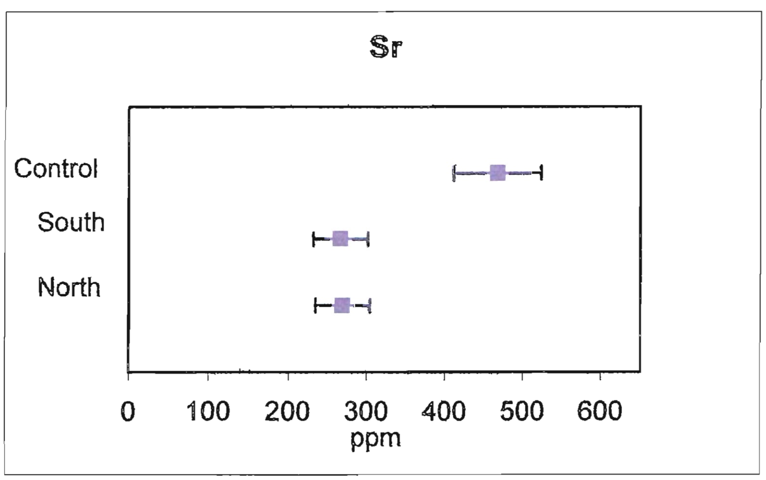


Figure 4.6: ANOVA results for Sr. Individual 95% Confidence Intervals based on pooled standard deviation.

illustrated how the addition of Sr in association with Fluoride affected the dissolution of synthetic apatite. Sr and F both retarded apatite dissolution, although it was much greater for F, and when used in partnership the affect was even greater than for Fluoride alone, and greater than would have been expected if they were added separately, suggesting a synergistic relationship for the two trace elements (Curzon and Cutress, 1983). Herbeson and Handelman (1975, in Curzon and Cutress, 1983), looked at the affects of several trace elements in vitro with effects on acid production and hydroxyapatite dissolution. Their work was of great interest because the study reflected trace element concentrations based on communal water supplies of a previous study conducted by Curzon et al (1970, In Curzon And Cutress, 1983). The study showed that there was a significant effect with Sr and F in combination that reduced the hydroxyapatite dissolution, which was not due to any other factors influencing the results (Curzon and Cutress, 1983).

4.9.4 Discussion of Cobalt (Co)

Cobalt is significantly depleted within moose populations of CBH (Figure 4.7), not being detected in the population North of the Park. The detection limit for cobalt was 0.1ppm for the lower limit and 120ppm for the upper limit.

Cobalt concentrations generally occur in highest concentrations in the liver, kidneys and bones, although it is widely distributed throughout the bodies of most animals with no excessive accumulation within any particular organ or tissue (Underwood, 1971).

The dietary benefits of cobalt have been known for decades. In 1935 Australian researchers described the effects of "coast disease" and "wasting disease" among sheep and cattle to be the result of insufficient cobalt in dietary intake (Underwood, 1971). Co has a relationship with vitamin B_{12} synthesis, and Co deficient animals lack the ability to synthesize vitamin B_{12} properly.

Victims of this debilitating disease initially thrive and grow as normal drawing upon B_{12} reserves within the liver and other tissues for a period of weeks to several months. Following this is usually a gradual loss of appetite and failure of growth or loss of body weight, and in some animals there is evidence of hypoplasia within erythrogenic tissues and in bone marrow (Underwood, 1971) due to the restriction of vitamin B12 synthesis, which consequently increases other metabolic disturbances (Frank et al, in press). Hypoplasia in enamel is well documented, and is a defect that results in a lesser quantity of enamel covering the dentin that would normally be present that occurs during matrix formation, and cannot be predicted with any reliability even in the most severe form of the disease (Bhaskar, 1991).

Frank et al (in press) investigated the Co within moose of Nova Scotia, and concluded that Co and vitamin B_{12} was deficient within the herds of the Tobeatic and C.B.H regions, but was also observed to some extent within other mainland populations. The problem of 'moose sickness' was the focus of the study, which results in symptoms resembling that of 'coastal' or 'wasting disease'.

There is no clear role between Co concentration of enamel and dental disease. Within humans, only two known studies have been conducted analysing for affects of Co. Navia (1970, in Curzon and Cutress, 1983) concluded that Co was a doubtful as a trace element that promoted dental Caries. Driezen et al (1952, in Curzon and Cutress, 1983) could find no relationship with Co concentration in saliva with dental caries.

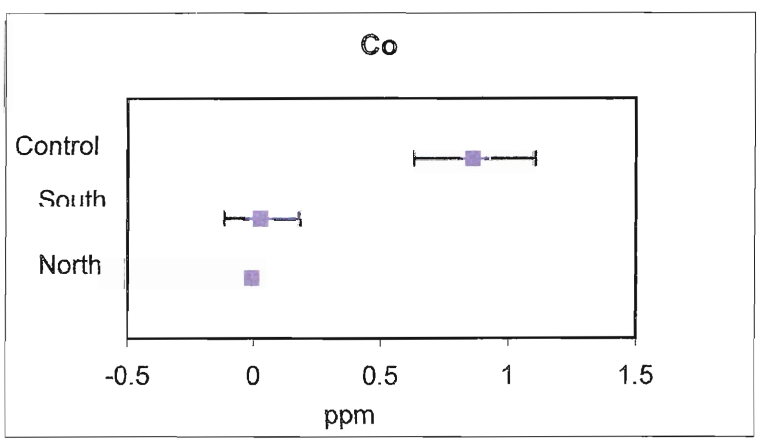


Figure 4.7: ANOVA results for Co. Individual 95% Confidence Intervals based on pooled standard deviation.

In animal experiments, a study conducted by Hendershot and Forsaith (1958, in Curzon and Cutress, 1983) showed there was a higher incidence of caries in rats that were fed Co-EDTA, yet they did not attempt to separate the effect of EDTA alone.

4.9.5 Discussion of Tin (Sn)

Tin is significantly depleted in the C.B.H population compared to the control population (Figure 4.8). Chemically tin is non-toxic and non-reactive, and there is no evidence to support tin as performing any essential functions within plants and animals. It has a low absorption rate and low retention in animal tissues so therefore is generally non-toxic (Underwood, 1971).

The majority of studies conducted with Sn in relation to dental disease have been in the form of SnF_2, fluoride being a known inhibitor of caries. It is therefore not clear whether Sn has an affect on caries by itself, as a separate entity of F (Curzon and Cutress, 1983). SnF in mouth rinse inhibits acid formation in plaque and also lessens the formation of plaque (Svatun and Attramadal, 1978, in Curzon and Cutress, 1983). Attramadal and Svatun (1980, Curzon and Cutress, 1983) showed that Bacteria in the oral environment show a rapid uptake of Sn greater than other metal cations.

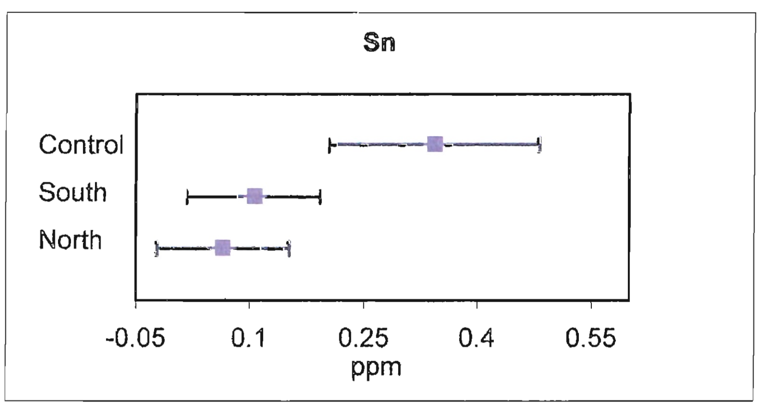


Figure 4.8: ANOVA results for Sr. Individual 95% Confidence Intervals based on pooled standard deviation.

The presence of Sn^{2+} may have an inhibitory effect on growth rate and metabolism of bacteria (Aikin and Dean, 1976, Curzon and Cutress, 1983). This is a possible reason for Sn having inhibiting affects on caries (Curzon and Cutress, 1983).

Studies conducted on Sn itself and its relationship with dental disease is very limited, although there has been considerable interest recently according to Curzon and Cutress (1983).

East Kemptville mine is situated in close proximity to the Tobeatic area, where the control population inhabits. This area is considered a major tin province, and when it was operating it was the largest Tin mine in North America (Zentilli, personal communication, 2004). This correlates with our results, which indicate higher levels of Sn within the enamel of the control population. Curzon and Cutress (1983) also describe the marked difference in trace element concentration between different geographic locations. The differences in concentrations between geographical areas would be highly likely as a result of geochemistry in the area.

4.9.6 Conclusions

Many investigations of trace elements and disease have been conducted for other species and also between species of ruminants, yet there are no data available that adequately describe the recommended dietary intake of trace elements for moose, and biological values from one species to another is always open to question (Frank et al, 2003).

Ba and Sr have both been implicated to result in poorer calcification of bones, and Cobalt is well documented in resulting in wasting disease, loss of appetite and even hypoplasia. The weakening of the teeth in the C.B.H may be a result of poor calcification, which ultimately affects the crystal structure within the enamel framework, and also hypoplasia, which is a defect resulting in the enamel being insufficiently represented in teeth that are affected causing enamel to become weak and vulnerable to caries, and possibly fractures.

Pb should not be excluded, because as Underwood (1971) states, Pb in deficient quantities should not be discounted in relation to performing any biological function. Further investigation should be considered to examine if there are any Fe deficiencies within the moose in response to experiments described by Frieden (1984).

Sn is chemically non-toxic and non-reactive, and has not been proven to have any essential role in the biological functions of plants or animals (Underwood, 1971). The correlation between the East Kemptville tin mine that occurs in close proximity to the control population, and the elevated levels of Tin within the enamel of the control, provides good evidence that trace elements can vary geographically, as a result of the geochemistry within the soils and bedrock. Based on the results for Sn it is possible to determine the origin (where a moose lived) based on tooth geochemistry

There are significant indications based on the results thus far. Further investigation is required, as our results are based on the assumption of only one control population and the populations of the C.B.H. The use of more than one control population with larger sample sizes to reduce any sampling error present would be required before any strong conclusions can be drawn.

4.10 <u>Healthy Vs North of the Park & Healthy Vs South of the Park</u>

Rubidium, Gallium, Yttrium and Thorium show significantly different values within the population North of the Park compared to the control. Rubidium, Yttrium and Thorium are all depleted, while Gallium shows elevated levels. There are no significant differences of elements South of the Park compared to the control area.

4.10.1 Rubidium (Rb)

Rubidium is significantly depleted in the population North of the Park compared to both South of the Park and the control population (Figure 4.9). Biological interest has been stimulated because of rubidium's close affiliation with potassium and its presence in living tissues in higher concentrations, relative to those of potassium, than in the terrestrial environment (Underwood, 1971).

Because of its close resemblance to potassium, all plant and animal cells are freely permeable to rubidium, at rates comparable to potassium (Underwood, 1971). According to Frieden (1984) rubidium cannot be excluded from being an essential, even though it has been proven to be essential at accurately determined levels.

Rubidium is not normally taken up by calcified tissues any more than by other parts of the body, and appears to be a normal constituent of enamel, yet due to its close physiochemical relationship with potassium it should be investigated further (Curzon and Cutress, 1983).

4.10.2 Discussion of Yttrium (Y)

Yttrium is significantly depleted within the moose population North of the Park, and although relatively less South of the Park, it is not significantly depleted in this population (Figure 4,10). No information could be found in the literature regarding yttrium's role in biological processes.

The role of Y in relation to dental caries is still unknown, although studies done by Castillo-Mercado and Bibby (1973, in Curzon and Cutress, 1983) produced significant alterations in rat molar morphology by injection of Y during the period of tooth development in rats. Castillo-Mercado and Ludwig (1973, in Curzon and Cutress, 1983) yielded results in an associated study showing that rats being fed a cariogenic diet showed significantly lower caries prevalence when injected with Y. Rats receiving Y through drinking water also displayed lower caries prevalence, but not at a significant level.

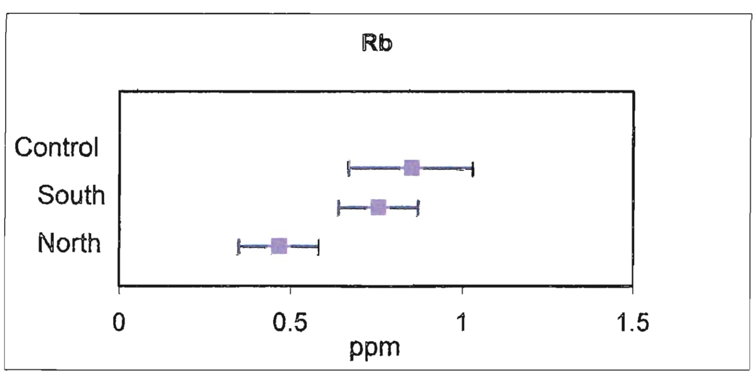


Figure 4.9: ANOVA results for Rb. Individual 95% Confidence Intervals based on pooled standard deviation.

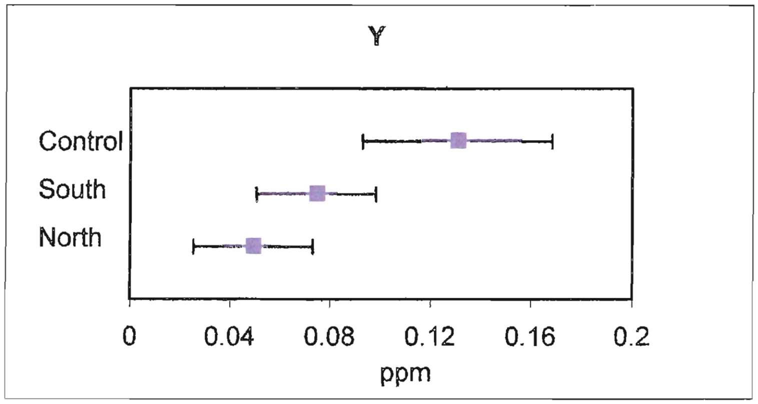


Figure 4.10: ANOVA results for Y. Individual 95% Confidence Intervals based on pooled standard deviation.

4.10.3 Discussion of Thorium (Th)

Thorium is significantly depleted in moose North of the Park compared to the control population (Figure 4.11). No information was found in the literature regarding the role of Thorium in biological functions and dental disease.

4.10.4 Discussion of Gallium (Ga)

Gallium is significantly elevated in the population North of the Park compared to population South of the Park and the control population (Figure 4.12). There is no information in the literature regarding gallium as performing any essential biological function in animals, or in dental disease. Although it has been shown that gallium is an essential micronutrient of the fungus *Aspergillus niger* and the duckweed *Lemma minor* (Fairbridge, 1972).

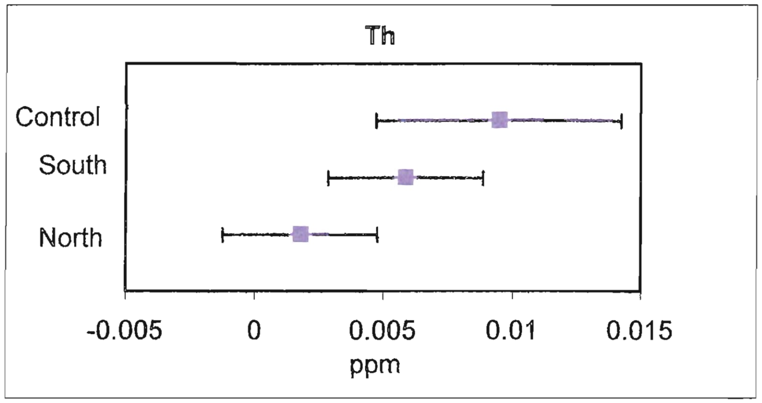


Figure 4.11: ANOVA results for Th. Individual 95% Confidence Intervals based on pooled standard deviation.

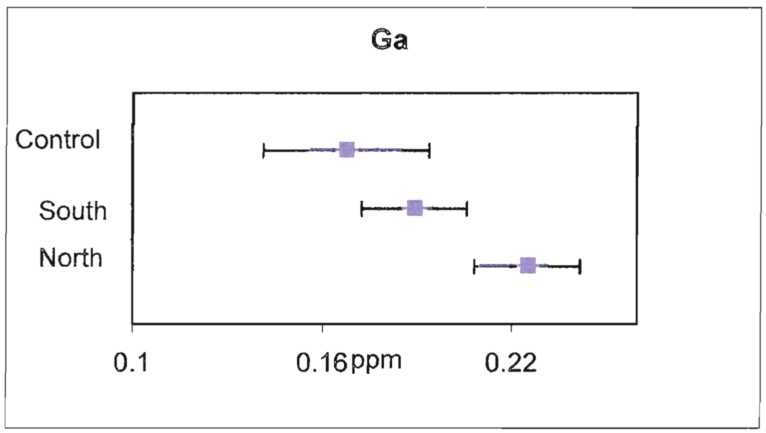


Figure 4.9: ANOVA results for Rb. Individual 95% Confidence Intervals based on pooled standard deviation.

4.10.5 Conclusions

The results for Rubidium, Gallium, Yttrium and Thorium are unclear, particularly for Rubidium and Gallium, which are significantly depleted in the population North of the Park compared to both the control population and the population South of the Park. Although, if the geology differs between North and South of the Park this may account for the differences, as moose very rarely cross over between North and South of the Park, and when they do it is generally to replenish populations (Nette, personal communication, 2004).

Yttrium is the only element discussed that has information in the literature to implicate it as having a role in dental disease, showing a decrease in caries when in increasing concentrations. This may be of significance as yttrium is depleted in the North, and, although not significant, yttrium does appear to be present in lesser amounts in the south as compared to the control also.

Results for Rb, Ga and Th do not provide any strong conclusions, but may warrant a further investigation with more than one control and increased sample sizes to reduce any sampling error that may be associated with this study.

4.11 Correlations between Element (ppm) and Breakage score

The correlation data for element concentration and breakage score is very unclear. The correlation trends that are seen in the population North of the Park (Appendix F) are not always consistent with the trends in correlation to the population South of the Park (Appendix G). R-square values are very low in some cases, yet the values can be higher in other cases. The fact that there is disagreeance in correlation trends between the two populations, presents a problem for interpretation, as we would expect the data to follow the same trends.

4.11.1 Conclusions

Correlation data are inconclusive. Undoubtedly the number of samples is so far insufficient to draw useful conclusions, yet these are the first data available for moose teeth in the region, and raise interesting questions. By repeating the experiment with a larger sample size to reduce error associated with the sampling, and reproducing this experiment may further aid in understanding the correlation data. At present, there is no information or studies to compare our correlation data with and therefore, these data must be classified as inconclusive.

4.12 Summary of Chapter

Macrofractures are the type fractures visible with the naked eye. Based on work done by Smith (1992), Nette and Power (Unpublished, 1999) described and categorized teeth from the C.B.H area to determine the state of their teeth in terms of the amount of fracturing present.

Brown stains running perpendicular to the enamel surface are evidence of initial fracturing. The stained fractures appear to weaken the enamel structure, eventually breaking off. After breakage has occurred, the tooth surface will become polished and stained brown again. This is an important characteristic of the fracturing because it implies that the moose was living for a period of time after breakage occurred. When fresh breaks occur, the staining and rounded surface will not be present and can imply that breakage occurred just prior to the death of the animal, or even that it occurred after death.

Within the CBH, results show that 5 elements, Barium, Lead, Strontium, Cobalt and Tin show significantly depleted levels in the C.B.H moose compared to that of the control population.

Barium and Srtrontium have both been implicated to result in poorer calcification of bones, and Cobalt is well documented in resulting in wasting disease, loss of appetite and even hypoplasia. The weakening of the teeth in the C.B.H may be a result of poor calcification, which ultimately affects the crystal structure within the enamel framework, and hypoplasia, which is a defect resulting in the enamel being insufficiently represented in teeth that are affected causing enamel to become weak and vulnerable to caries, and possibly fractures.

The correlation between the East Kemptville tin mine that occurs in close proximity to the control population, and the elevated levels of Tin within the enamel of the control, provides good evidence that enamel trace element concentration can vary geographically, as a result of the geochemistry within the soils and bedrock.

Yttrium is depleted in the North, and, although not significant, yttrium does appear to be present in lesser amounts in the south compared to the control. Yttrium has also been implicated in dental disease, showing a decrease in caries when in increasing concentrations.

Chapter 5: Microfractures

5.1 Introduction

Microfractures are fractures that cannot be seen with the naked eye, and require the use of a high-powered microscope to investigate their prevalence within the enamel structure of the moose incisors. This chapter will combine the work of Graves and Casey (2002, unpublished), and new data obtained in 2004. Graves and Casey (2002, unpublished) investigated and categorized characteristic microfracturing, and Microprobe data, within both the control group of Tobeatic, and the unhealthy moose population of CBH. Graves and Casey (2002, unpublished) examined fracturing that was present in both unhealthy and healthy populations, and also unique fractures present only in the unhealthy CBH population. This Chapter will also introduce new data obtained from utilising the Microprobe at Dalhousie University.

5.2 Description of Microfractures

The following discussion and categorization of fracturing was identified analysing cross-sections of incisors under reflective light using the petrographic microscope (Zeiss Axioplan (German)) in the Fission Track Laboratory, Dalhousie University (Graves and Casey, 2002, unpublished). This method was employed following the example set by Young and Marty (1986).

The teeth were selected as being a representative sample of the entire populations, and were chosen on the basis of degree of fracturing (Breakage score) and the area in which the moose was located at the time of harvesting. Because there was no indication that the sex of the animal was a determinant facture when analysing the degree of breakage (Breakage score) (Nette, personal communication, 2004), it was therefore not considered for this analysis also.

Graves and Casey (2002, unpublished) analysed a representative sample of 4 moose incisors; Healthy, Breakage score 1(CBH), Breakage score 2 (CBH), and Breakage score 3 (CBH), and divided their analysis into three subsections of degree of breakage; healthy (Tobeatic), unhealthy, partially brittle (C.B.H), and unhealthy, very brittle (C.B.H).

Five different type fractures were common to all teeth analysed, healthy, 1 (none/slight), 2 (moderate) and 3 (severe), and two types of fracturing were unique to the very brittle CBH teeth. Figure 5.1 illustrates a cross-section of a tooth that is visible under the petrographic microscope using reflected light. From Figure 5.1 we can visibly identify the main components of the tooth, dentin as being the dark area on the lower right hand side, the dentino-enamel junction where the enamel forms a protective layer over the dentin, and the outer enamel.

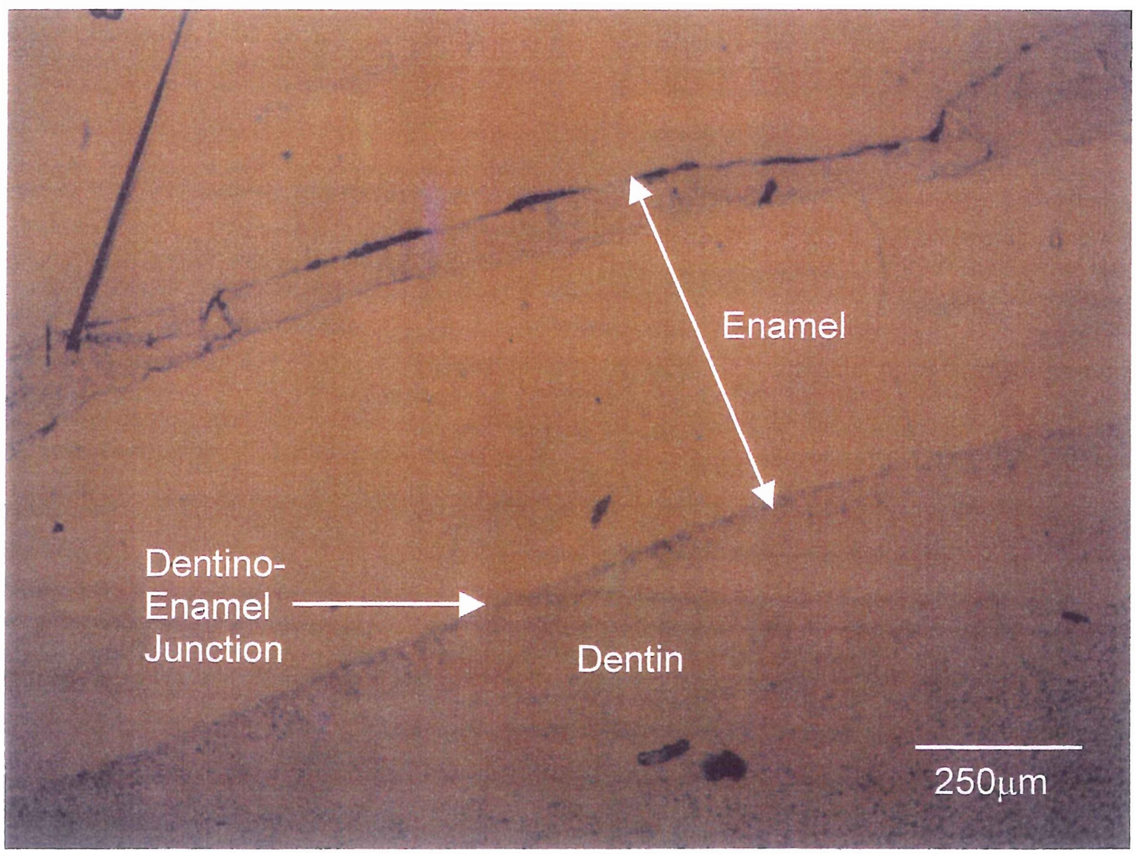
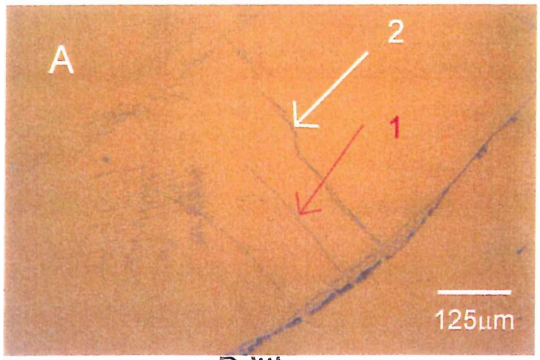
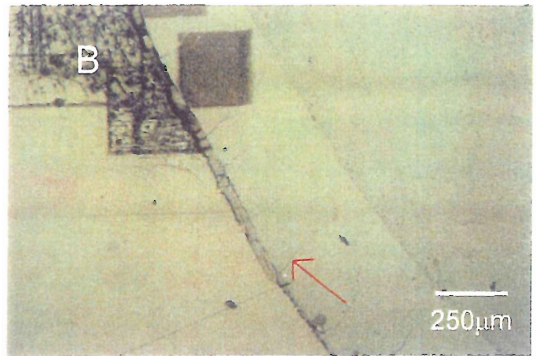


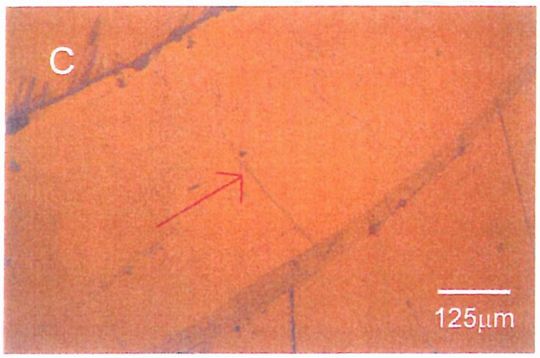
Figure 5.1: Cross-section of incisor under reflected light. Enamel, Dentin and Dentino Enamel Junction (DEJ) are clearly visible (Graves and Casey, 2002 unpublished).



Brittle



Partially Brittle

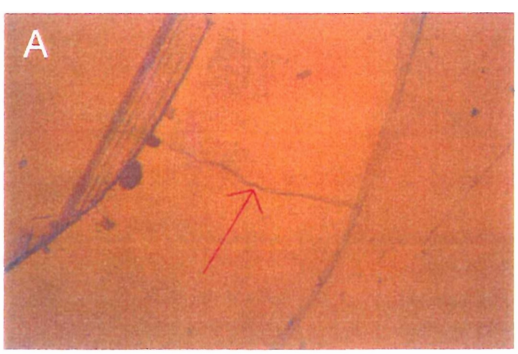


Healthy

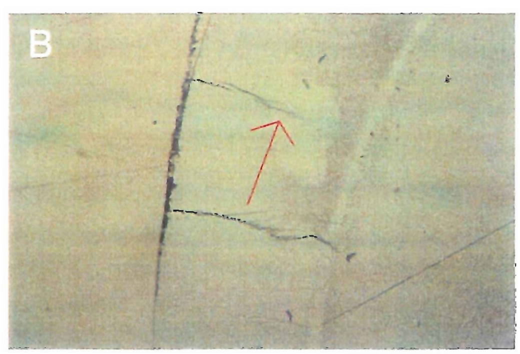
Figure 5.2 (A) Type 1 and Type 2 fractures visible in a brittle tooth (breakage score 3) from C.B.H (B) Type 1 fracturing visible within a partially brittle tooth (breakage score of 2) from C.B.H and (C) Type 1 fracturing visible in a healthy tooth from the control area (Graves and Casey, 2002, unpublished)

Type 1 fractures were described by Graves and Casey (2002, unpublished) as being long, narrow, shallow and following the same orientation of the apatite rods. Figure 5.2 (a, b and c) illustrates the occurrence of this fracture type, which is evident in all teeth types, both healthy and unhealthy.

Type 2 fractures were characterized by Graves and Casey (2002, unpublished) as being similar to the type 1 fractures, only that they were longer and wider than type one fractures. Type two fractures also occur in all teeth



Healthy



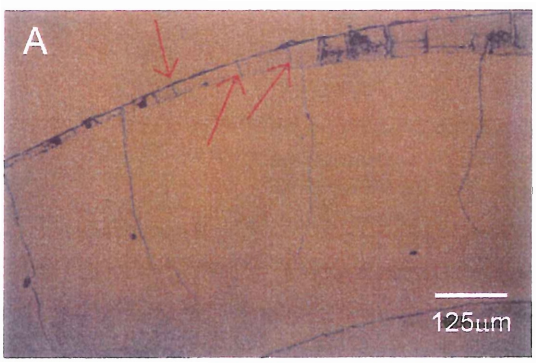
Partially Brittle

Figure 5.3: Type 2 fracturing (A) evident within a healthy to from the control population. A type 2 fracture (B) visible within a partially brittle tooth (Breakage score of 2) from C.B.H (Graves and Casey, 2002, unpublished)

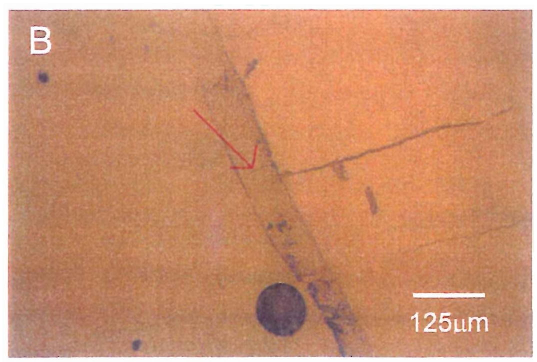
types, healthy and unhealthy, and follow an orientation similar to the apatite crystals. Type two fractures are illustrated in the unhealthy teeth (Figure 5.2a and Figure 5.3b), and in the healthy teeth (Figure 5.3a).

According to Graves and Casey (2002, unpublished), type 3 fracturing is limited to the outside layering of the enamel. It is much smaller than the previous fracture types mentioned, and is characteristically short and shallow fracturing. It does, however, follow the same pattern as the previous two fractures in terms of orientation in that it follows the orientation of the apatite crystal structure. Figure 5.4 (a, b and c) illustrates type three fracturing that is common amongst all teeth.

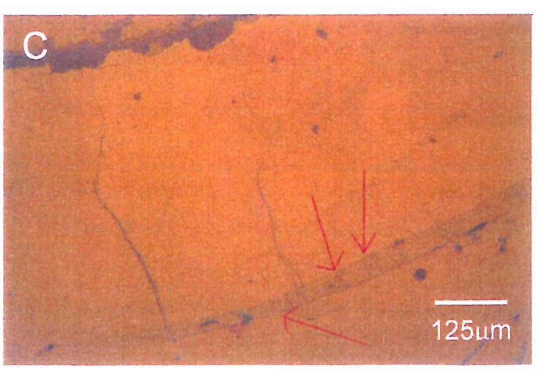
Type 4 fractures were interpreted by Graves and Casey (2002, unpublished) as being the longest and widest of all fracture types. They are not limited to the enamel layering, but extend through to involve the dentine as well. Type 4 fractures were described also as being the deepest of the cracks and that they were often in filled with an unknown substance (Graves and Casey, 2002 unpublished.



Brittle

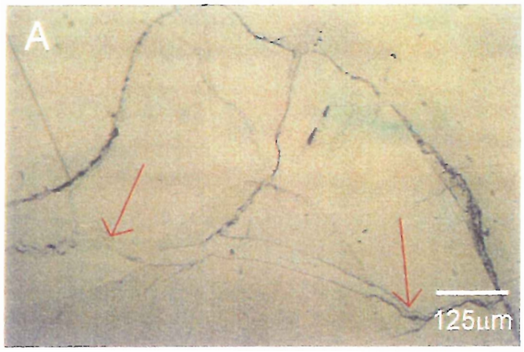


Partially Brittle

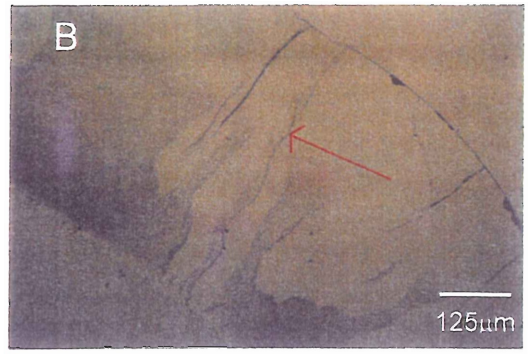


Healthy

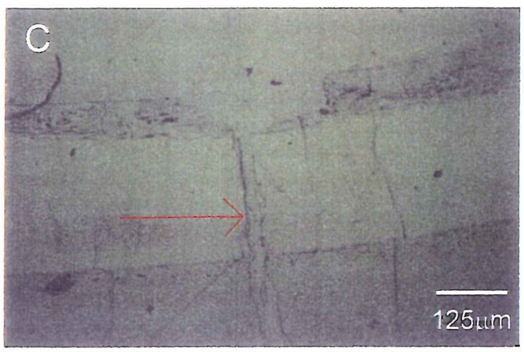
Figure 5.4: Type 3 fracturing (A) evident within a brittle tooth (breakage score 3) from C.B.H. Type 3 fracturing (B) within a partially brittle tooth (breakage score 2) from C.B.H. Type 3 fracturing (C) visible within a healthy tooth from the control population (Graves and Casey, 2002, unpublished)



Brittle



Partially Brittle



Healthy

Figure 5.5: Type 4 fracturing (A) visible within a brittle tooth (breakage score 3) from C.B.H. Type 4 fracturing (B) visible within a partially brittle tooth (breakage score 2) from C.B.H. Type 4 fracturing (C) visible within a healthy tooth from the control area. Notice how it begins at the enamel surface and extends into the dentin. (Graves and Casey, 2002, unpublished).

Figure 5.5 (a, b and c) shows the features of a type 4 fracture documented by Graves and Casey (2002, unpublished)

Type 5 fractures are the final fracture type common to all teeth. These fracture types were generally long, narrow, and wavy running parallel and with close proximity to the Dentino-Enamel junction (Graves and Casey, 2002 unpublished). Figure 5.6 (a, b, c and d) illustrates the nature of these fracture types, with figure 5.6d showing a magnified view from a healthy tooth.

The final type of fracturing was unique to the CBH populations limited to animals that exhibited a breakage score of 3.Two fracture types (A & B) were identified as occurring within the incisor studied by Graves and Casey (2002, unpublished). Type A was a long jagged line cutting 45 degrees across the enamel layer, from the Dentino-Enamel Junction to the outer edge of the enamel (Figure 5.7). Type B fractures were very randomized fracturing in terms of directions, they are very jaggered, and are restricted to the outer $^{1}/_{3}$ of the enamel (Figure 5.7).

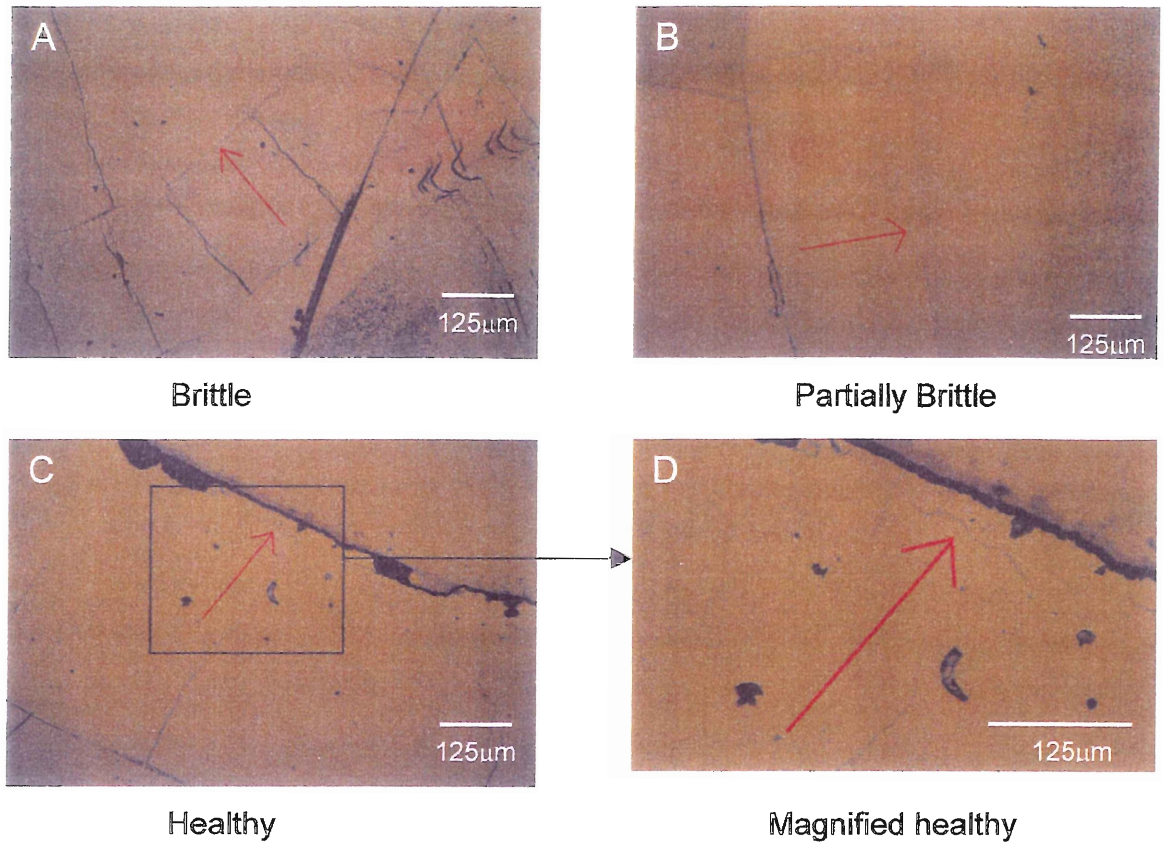


Figure 5.6: Type 5 fracturing (A) visible within a brittle tooth (breakage score 3) from C.B.H. Type 5 fracturing (B) visible within a partially brittle tooth (breakage score 2) from C.B.H. Type 5 fracturing visible within a healthy tooth from the control population. Magnified view (D) of a type 5 fracture. Notice it runs parallel, and not perpendicular like the other fracture types. (Graves and Casey, 2002, unpublished)

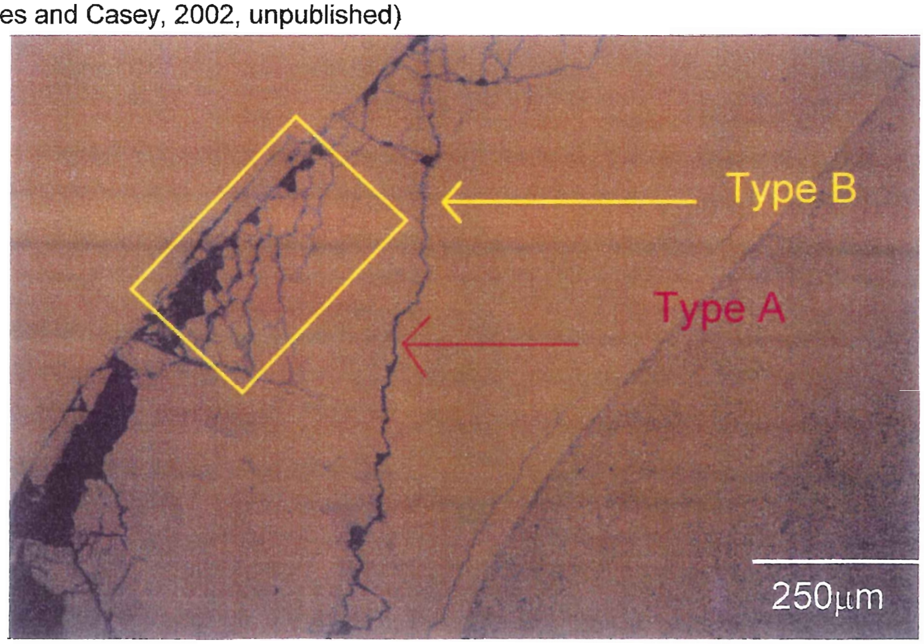


Figure 5.7: Type A fracture (red arrow) extending through the entire enamel framework at a 45^0 angle. Type B fracture (yellow arrow) occurs in the outer enamel and exhibits a dendritic pattern (Graves and Casey, 2002, unpublished)

An interesting feature that was not documented by Graves and Casey (2002, unpublished) is the fracturing that appears to cease at the outer most enamel layer, where another layer of enamel has appeared to have been calcified. Figure 5.8 (a, b and c) illustrates this phenomenon, as we clearly see that type 1 and 2 fractures will cease at the outer layer of enamel and also type 3 fractures will not involve the rest of the enamel, only the outside layering.

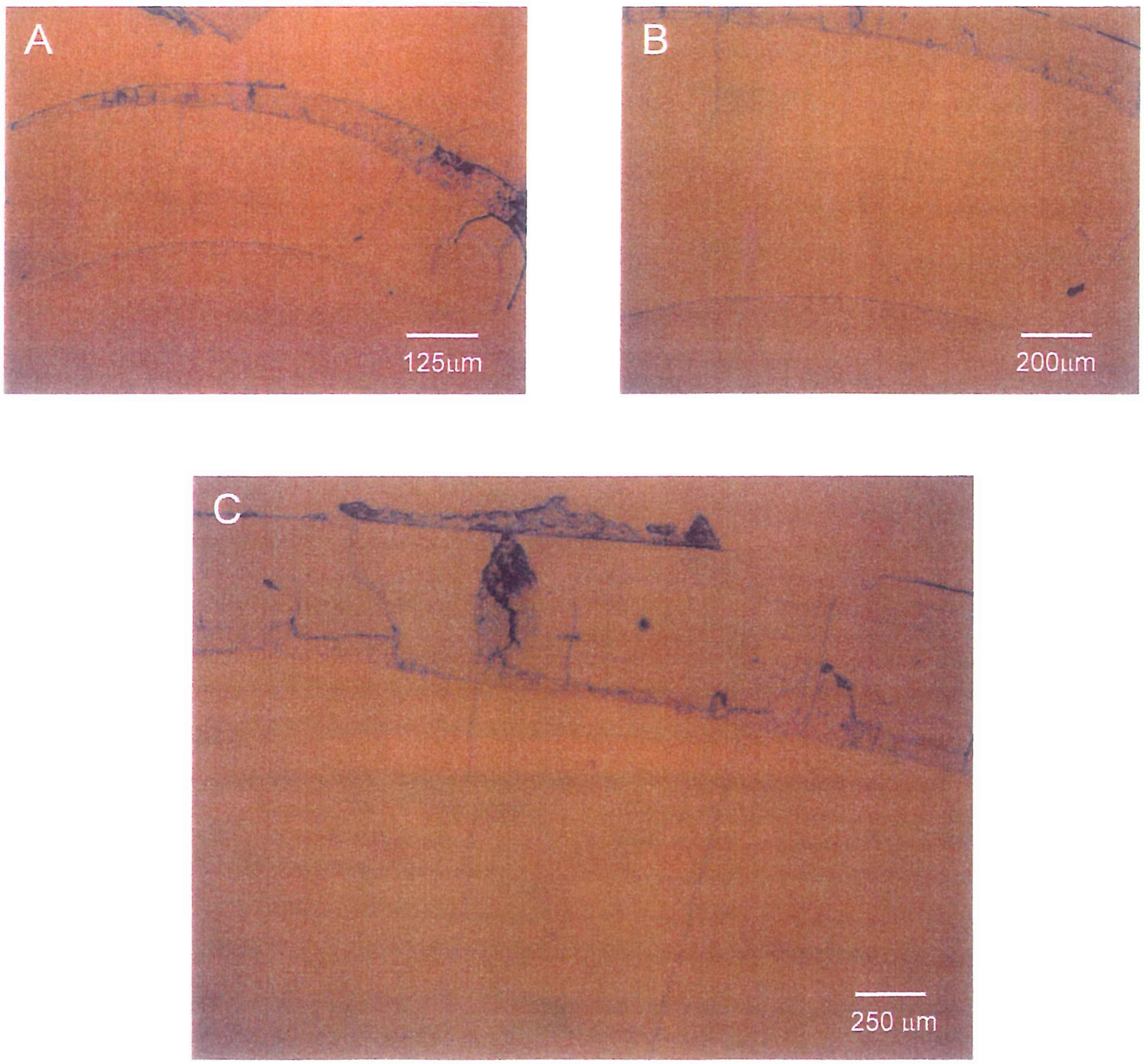


Figure 5.8: Section of enamel from M051 (control population). A, B, and C are different locations within the enamel at varying magnifications. Notice that the fracturing ceases to include the outer enamel (Graves and Casey, 2002, unpublished)

5.2.1 Scanning Electron Micrograph (SEM)

Figures 5.9 to 5.13 are sections of enamel that were photographed using the Scanning Electron Micrograph (SEM) in the microprobe lab at Dalhousie University. The enamel samples were mounted onto one individual slide and prepared at the same, with no difference in preparation between individual samples. This is important to note because we see varying degrees of fracturing amongst these four grains.

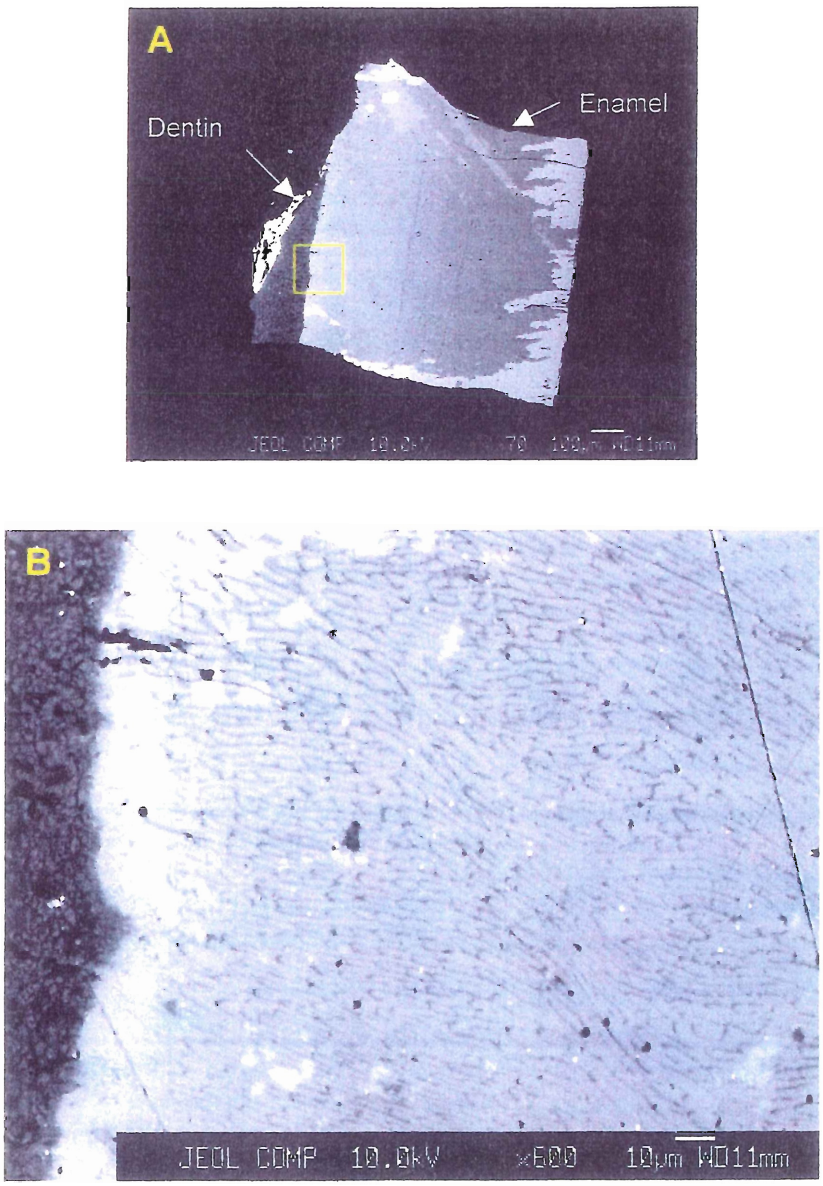


Figure 5.9: (A) Scanning Electron Micrograph (SEM) image of sample M056. (B) Magnified section of M056. Notice the wavy crystal structure.

The fracturing present within these samples appears to be similar in nature and orientation to the microfractures described by Graves and Casey (2002, unpublished). Also visible in the magnified sections of Figure 5.9b, Figure 5.10b and Figure 5.11b are the various prism structure patterns that are produced by cutting different planes of the enamel (Figure 3.3a).

Figure 5.9 is a sample taken from M052, a healthy moose from the control population. This sample shows very little fracturing.

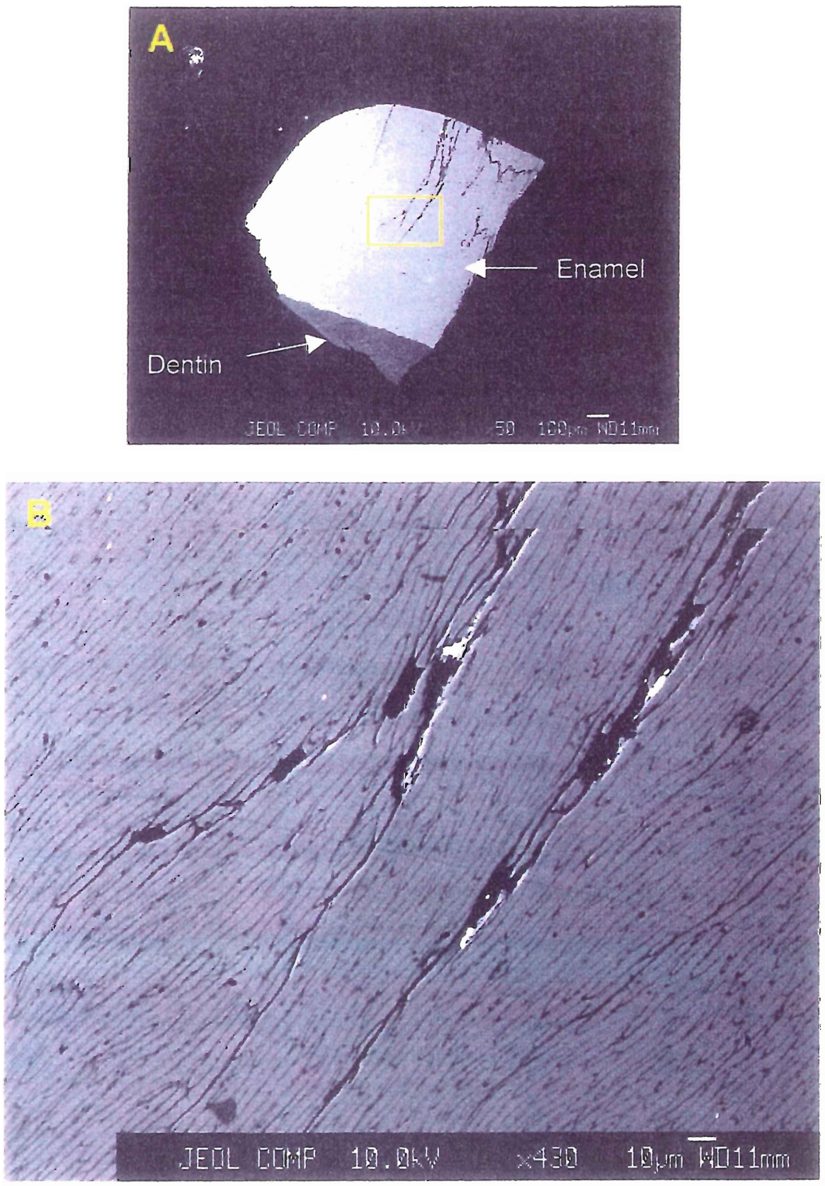


Figure 5.10: (A) Scanning Electron Micrograph (SEM) image of sample M027 (South of Park with breakage score 3) (B) Magnified section of M027. Notice the wavy crystal structure and orientation of fracturing.

Figure 5.10 is an enamel sample taken from M027, which exhibited a breakage score of 3 and was from the population South of the Park. Higher rates of fracturing are visible within this tooth sample compared to Figure 5.9.

Figure 5.11 is an enamel sample taken from M012, which exhibited a breakage score of 3 and was from the population North of the Park. Also visible are a higher frequency of fracturing compared to Figure 5.9.

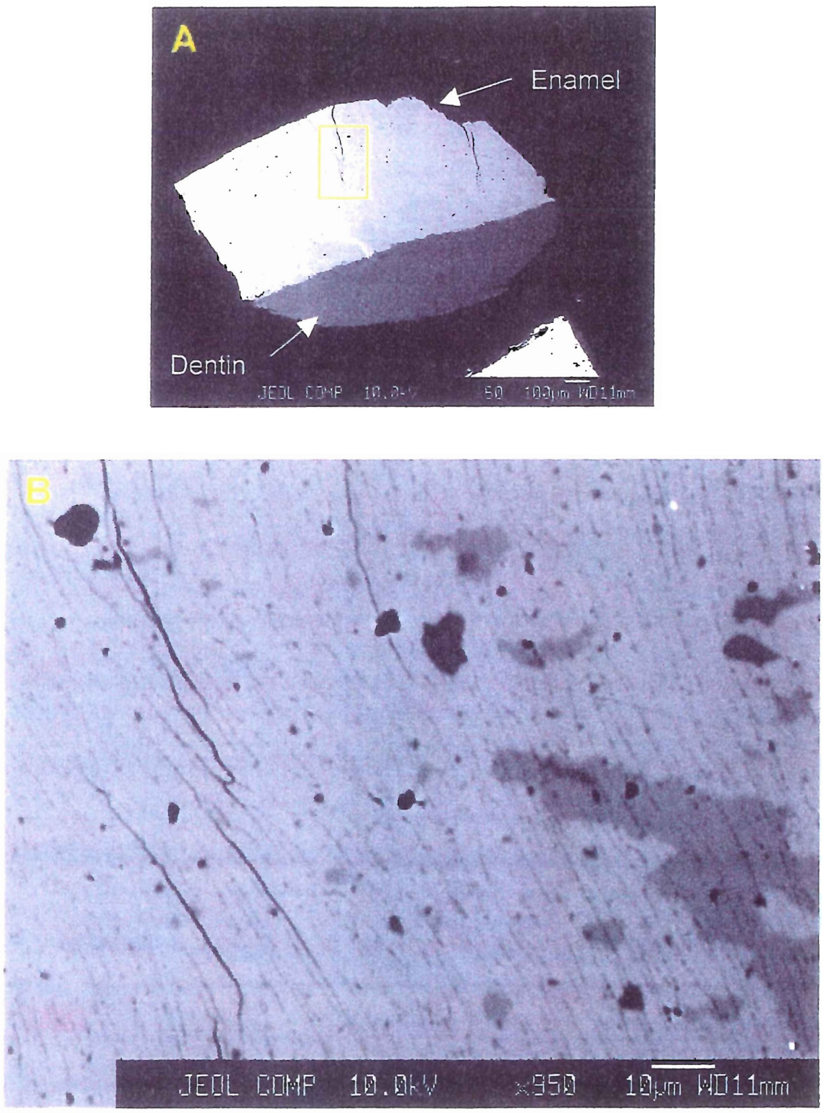


Figure 5.11: (A) Scanning Electron Micrograph (SEM) image of sample M012 (North of Park with breakage score 3) (B) Magnified section of M012. Notice the wavy crystal structure and orientation of fracturing.

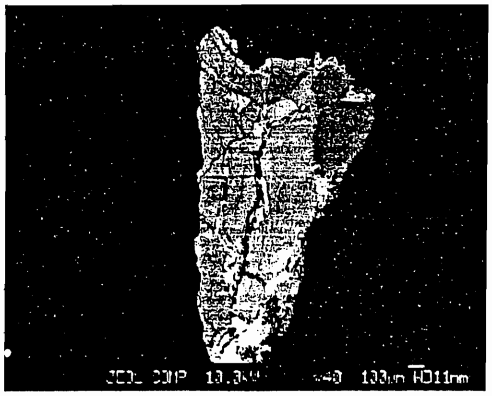


Figure 5.12: Scanning Electron Micrograph (SEM) image of sample M030 (North of the Park with breakage score 3). Notice the degree of fracturing.

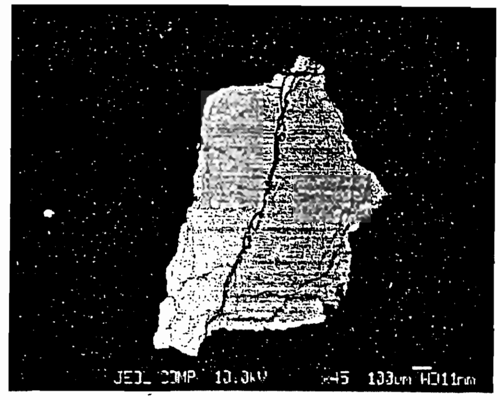


Figure 5.13: Scanning Electron Micrograph (SEM) image of sample M042 (South of the Park with breakage score 3). Notice the degree of fracturing.

Figure 5.12 and 5.13 are both from C.B.H (North and South of the Park respectively) with breakage score of 3. These samples are of interest due to the nature of fracturing. Unlike the previous samples, the fracturing has no preferred orientation and seems to be random and bearing close resemblance to Type B fracturing described by Graves and Casey (2002, unpublished). Prior to the microprobe analysis the samples did not exhibit this degree of fracturing, it was only when they were inserted into the microprobe that they began to fracture. This type of fracturing was not limited to the unhealthy teeth, and did occur in the one control sample, although it did occur in a higher frequency within the unhealthy teeth ($^1/_4$ in Control, $^3/_4$ South of the Park, and $^3/_4$ North of the Park)

5.2.2 Discussion of Microfractures

There is no knowledge of microfractures occurring in the literature, and therefore comparisons with other studies cannot be made. Although, lamellae in teeth were initially misinterpreted as being 'cracks'. The following discussion on enamel lamellae and Stripes of Retzius was taken from Bhaskar (1991), unless otherwise noted.

In dentistry, the term 'cracks' was originally used to describe narrow, fissurelike structures that are seen in almost all enamel surfaces. It has since been demonstrated that these 'cracks' are in fact dental lamellae, thin, leaflike structures that extend from the enamel surface toward the dentino-enamel junction (DEJ). They occur in the enamel fairly even spaced, and longer lamellae appear thicker than short ones, and occasionally they will extend into the dentin. In cross sectional views, enamel lamellae may be confused with cracks. Lamellae consist of organic material with little mineral content. It has been suggested that enamel lamellae may be a site of weakness in a tooth.

During cavity preparation, dentists are aware of the tendency of enamel to fracture along cleavage planes paralleling the course of the enamel rods (Avery, 1994).

Stripes of Retzius are lines or stripes (striae) that represent disturbed periods of growth. Accentuated stria of retzius (or Wilson band) is an observed in teeth of individuals as a result of some kind of 'trauma' (Goodman and Rose, 1990). A Wilson band will appear as a "marked incremental line", and has been associated with experimentally induced hypoplasias in sheep (Suckling and Thurley, 1984; in Goodman and Rose, 1990).

5.2.3 Conclusions for microfractures

Type 1 – 5 microfractures described by Graves and Casey (2002, unpublished) are most likely to have been misinterpreted as being enamel lamellae. Based on descriptions by Bhaskar (1991), the microfractures show very close resemblance to enamel lamellae. They occur in all the teeth analysed (Healthy and unhealthy), and the fracturing begins at the enamel surface, and extends towards the DEJ, with type 4 involving the dentin (Figure 5.5). The fractures are fairly evenly spaced, and this is particularly noticeable in Figure 5.4a. The longer fractures, such as type 4, are noticeably wider than smaller fractures, such as type 1 fractures.

Figure 5.8 could possibly be a Wilson band, although further investigation would need to be conducted to draw any hard conclusions because Graves and Casey (unpublished, 2002) were interested primarily in microfractures. It is not known whether this characteristic was present amongst all the teeth from the C.B.H population, and also the control population, or restricted to the unhealthy population.

Type A and Type B fracturing are of significance. These fracture types are only present within the C.B.H populations. Due to the nature of the fracturing, it appears that these samples are more brittle, allowing for fracturing to occur in any direction.

The SEM images provide high resolution, high magnification images of the enamel structure. The fracturing present cannot be ruled out as being a result of the preparation of the slide, which required a polished surface for the microprobe, as it is established that enamel does have a tendency to fracture along the cleavage planes that parallel the enamel rods (Avery, 1994). It is interesting to note, however, that there appears to be a higher incidence of fracturing having occurred within the unhealthy teeth, than with the healthy teeth.

The fracturing that has occurred in Figure 5.12 and 5.13 is very interesting. Although it occurred in both the C.B.H and control populations, the frequency was higher in the unhealthy teeth. These fractures occurred after insertion into the microprobe, and the cause of this problem was most likely a strain put on the samples due to the environment within the probe, which creates a vacuum affect (Stoffyn, personal communication, 2004).

Although the possibility of fracturing occurring as a result of sample preparation, or the microprobe environment cannot be ruled out, it is important to note that the frequency of fracturing was higher in the unhealthy teeth, which may indicate that the C.B.H samples are brittle and weak compared to the control population.

5.3 Microprobe analysis

Before the enamel was crushed to a fine powder, enamel grains were taken from twelve sample vials and were mounted onto a single slide. The slide was prepared by Gordon Brown, a thin section technologist at Dalhousie University, ready for analysis in the microprobe at Dalhousie University.

The following discussion on the Electron Microprobe is a summary of conversations with the Electron Microprobe technician, P. Stoffyn (2004). The Electron Microprobe works by focusing a beam on the sample; in this study it was a beam with a diameter of 5μm exciting an area on the sample that was

10μmin diameter. The beam bombards the surface with electrons, exciting the atoms within the sample, and as these samples return to their non-excited state they emit X-rays of characteristic wavelength to particular elements. Using a wavelength and/or dispersive detector, the electron microprobe collects and records the X-rays for each element within the sample. The sampled X-rays are compared to the X-rays of a standard control sample, which the machine is calibrated before a sample is analysed. X-ray counts are converted into element concentration to provide a complete chemical analysis of the elements of interest within the sample.

5.3.1 Results for Electron Microprobe

Nine elements were analysed in twelve samples, with a total of four samples from each population. Six points across the enamel surface were analysed, beginning from the inner enamel (Near the Dentino-enamel junction (DEJ)) towards the outer enamel. The nine elements that were analysed for were Calcium (Ca), Sodium (Na), Magnesium (Mg), Chlorine (Cl), Nitrogen (N), Fluorine (F), Oxygen (O), Sulphur (S) and Potassium (K). Of these nine elements, F and O were either not present or were present in levels below the detection limit of for the electron microprobe. The raw data output for the microprobe analysis is set out in appendix H.

Due to the nature of fracturing that occurred when the samples were placed into the electron microprobe (Figure 5.12 & 5.13), the orientation of the enamel surface was not always clear, and thus proving difficult in determining the location of the inner and outer enamel layers when performing any analysis across the enamel surface of these samples. Owing to this, the samples that will be included in the results are those that did not exhibit the fracturing such as Figure 5.12 & 5.13, only those samples where the outer and inner enamel could be distinguished (For example Figure 5.9). These include 3 samples from the control area (M051, M052 & M056), one from North of the Park (M012) and one from South of the Park (M027).

There is little variation in elemental concentration between the populations. Nitrogen shows an increase in concentration towards the outer enamel, magnesium and sulphur show decreasing trends towards the outer enamel, sodium, and chloride remain constant throughout the enamel whilst potassium varies within and between the samples and shows no trends. Appendix I illustrates these trends.

5.3.2 Discussion and Conclusion for Electron Microprobe

The microprobe data was slightly useful. There was no indication for the elements that were analysed being depleted/elevated within the study area compared to the control population.

Elemental concentration varying across the enamel framework was well illustrated between all samples, all following similar trends.

Overall, incisors of the different population showed similar trends and concentration.

5.4 Summary of Chapter

Five different type fractures were common to all teeth analysed, healthy, 1 (none/slight), 2 (moderate) and 3 (severe). Two fracture types were unique to the CBH populations limited to animals that exhibited a breakage score of 3.

With the use of the Scanning Electron Micrograph (SEM) within the Electron Microprobe at Dalhousie University, fracturing was evident within cross-sections of enamel at high magnification. The fracturing present within these samples appears to be similar in nature and orientation to the microfractures described by Graves and Casey (2002, unpublished).

Lamellae in teeth were initially misinterpreted by dentists as being 'cracks', and in cross-sectional views of enamel, lamellae may be misinterpreted as being 'cracks. Lamellae are, thin, leaflike structures that extend from the enamel surface toward the dentino-enamel junction (DEJ). They occur in the enamel fairly even spaced, and longer lamellae appear thicker than short ones, and occasionally they will extend into the dentin.

Graves and Casey (2002, unpublished) most likely misinterpreted lamellae as being 'cracks' within the tooth, as it is a common feature in all populations analysed.

Fractures that were present in the Scanning Electron Micrograph (SEM) images are most likely due to preparation of the samples and the process of microprobe analysis. It is important to note that the frequency of fracturing was higher in the unhealthy teeth, which may indicate that the C.B.H samples are brittle and weak compared to the control population.

During cavity preparation, dentists are aware of the tendency of enamel to fracture along cleavage planes paralleling the course of the enamel rods (Avery, 1994).

CHAPTER 6: Correlation between the Geochemistry of the Moose Teeth and Geochemistry of the surficial geology

6.1 Introduction

This chapter discusses the five elements that show significant differences between the study area and the control population, Barium, Lead, Strontium, Cobalt and Tin. Each element is discussed individually, and compared/correlated with the geology and geochemistry of the Cape Breton Highlands and areas within Shelburne County as described in previous studies in the literature. The information is drawn together and conclusions made based on the correlations with the teeth geochemistry and the geochemistry of the geology of the areas in question.

6.2 Cape Breton Highlands regional geology

The geology of the Cape Breton Highlands (C.B.H's) is composed of a complex assemblage of units. The area has been subdivided into three pre-Carboniferous tectonostratigraphic zones and/or terranes by Barr and Raeside (1989) (after Fyffe and Fricker (1987) and Williams et al. (1988)). The three units are referred to as the Blair River Complex, occurring in the northernmost region of the Cape Breton Highlands, the Aspy Terrane, occurring in the North-western region, and finally the Bras d'Or Terrane, occurring in the southern regions of the Cape Breton Highlands (Figure 6.1) (Barr and Jamieson, 1991; Barr et al 1987; Raeside and Barr, 1990).

6.2.1 Blair River Complex

The Blair River complex is composed of a distinctive assemblage of basement rocks including felsic and mafic gneisses, monzodiorite, anorthosite, and syentite (Neale 1963a, 1963b; Raeside et al. 1986; *In* Barr and Raeside, 1987). It includes the metamorphosed plutonic and stratified lithologies north of the Red River and west of the Wilkie Brook fault systems (Barr et al. 1987).

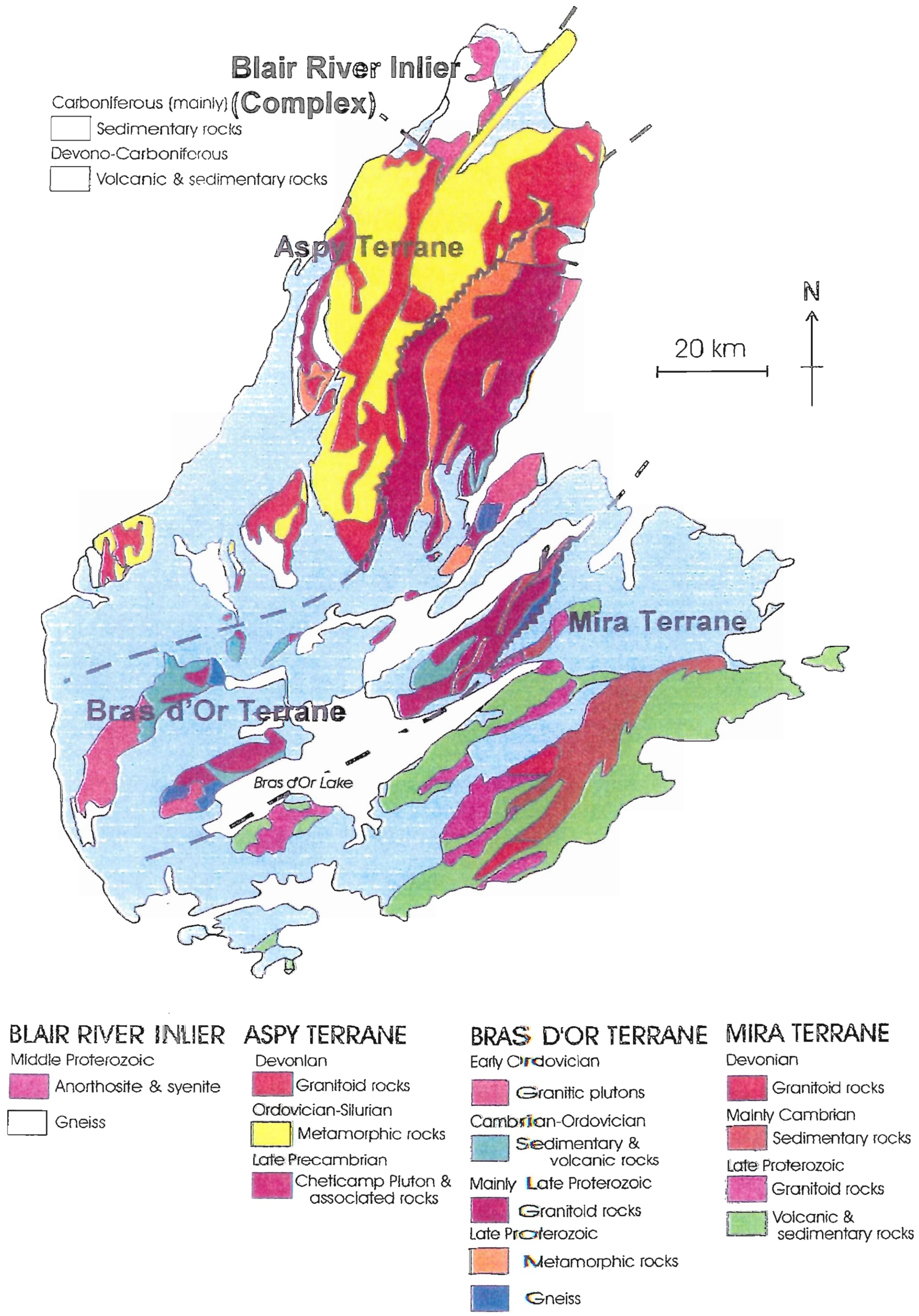


Figure 6.1: Simplified version of the complex geology of the C.B.H Notice the dominant unit of Aspy Terrane (Barr, 2002, *In* Walsh, 200, unpublished)

related dioritic, tonalitic, granodioitic, and granitic plutons are also present. Also particularly abundant in the plutons situated within the Highlands region are plutons containing magmatic epidote and high-aluminium hornblende.

The three proterozoic components of the Bras d'Or Terrane have been recognized in the Brookville Terrane of southern New Brunswick, and late Proterozoic gneiss, late proterozoic-early Cambrian calc-alkalic plutons and Ordovician granitic plutons have been reported in parts of the Hermitage Flexure of Southern Newfoundland (Raeside and Barr, 1990).

6.2.4 Geochemistry of the Cape Breton Highlands (CBH's)

Sangster et al (1990) examined marble-hosted zinc occurrences at Lime Hill and Meat Cove within the highlands region on Cape Breton Island. It was concluded that the area of study was geologically, geochemically, and isotopically (S and Pb) similar to a distinctive group of zinc occurrences hosted by Grenville Supergroup marble in Ontario, Quebec and New York. It was also concluded that minor elements commonly associated with base metal sulphide deposits, including Ag, Au, Sb, Co, Ni, and Mo are anomalously low compared to the similar Grenville Supergroup (Sangster et al. 1990).

6.3 Southwest Nova Scotia regional Geology

The control area situated in Southwestern Nova Scotia occurs within an area known geologically as the Meguma Supergroup (Figure 6.2). The Meguma Supergroup consists of thick metamorphosed siliclastic sequences, and is subdivided into two groups: Goldenville Formation and the overlying Halifax Formation, also referred to as the Goldenville-Halifax Transition (GHT) zone (Figure 6.3) (Graves and Zentilli, 1988). The Goldenville Group is composed of Cambrian greywacke with minor slates and the Halifax Group is composed of the Early Ordovician slates with minor greywacke (Schenk, 1995[a,b]).

The area is also known for the East Kemptville cassiterite deposit, North Americas only producing primary tin mine (Richardson et al., 1988).

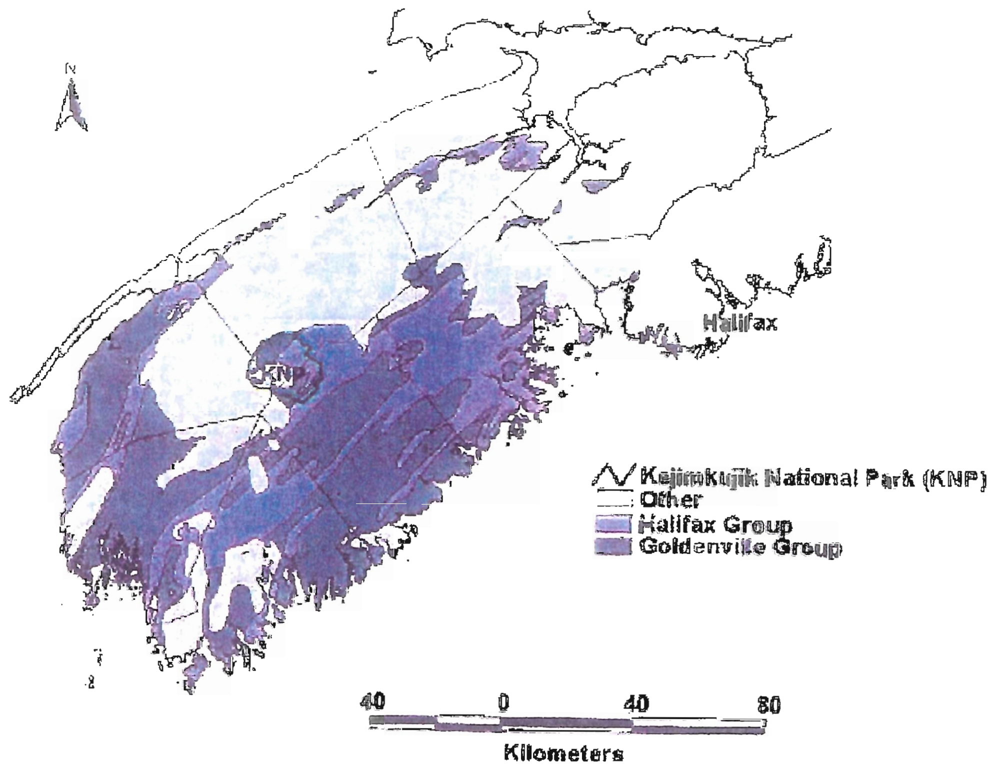


Figure 6.2: The Meguma Supergroup of southwestern mainland Nova Scotia, including the Goldenville Group and the Halifax Group. (Keppie, 2000, in Culgin, 2001, *In* Walsh, 2003, unpublished).

6.3.1 Geochemistry of Southwest Nova Scotia

East Kemptville, situated in close proximity to the control area, was for a while North Americas only producing primary tin mine, with a cassiterite (Tin Oxide) deposit of 58 million tonnes (0.165% tin) (Richardson et al., 1988). Manganiferous calcareous argillite and black slate at the base of the Halifax Formation are preferentially enriched in Mn, total C, Ba, Pb, Co, Zn, Cu, Mo, W and Au over average crustal values and over lithologies of the Goldenville Halifax transition zone (GHT) (Graves and Zentilli, 1988).

6.4 Discussion of trace elements of C.B.H moose teeth

The following discussions on the trace elements that show depleted levels, with respect to the control area, in the moose teeth enamel of the C.B.H moose, Barium, Lead, Strontium, Cobalt and Tin, is taken from Fairbridge (1972), unless otherwise noted.

6.4.1 Barium (Ba)

Barium has an atomic weight of 137.56 with atomic number 56, and belongs to the series of elements known as the alkaline earth elements. Metallic Barium does not occur naturally in nature. It occurs in nature as: barite $BaSO_4$; Witherite (The most common barium-bearing carbonate) $BaCO_3$; The less common barium minerals are: Barytoanglesite $(Ba, Pb)SO_4$; Bromlite $CaBa(CO)_3$. Barium silicates are uncommon and include the feldspar of Celsian $BaAl_2Si_2O_8$. In terms of the overall geochemical cycle, Barium most closely resembles Strontium, another important alkaline earth trace element of slightly smaller size.

In igneous and metamorphic rocks the most important occurrence of Barium is as a trace element in the tectosilicate mineral, orthoclase feldspar, yet orthoclase from the late stage pegmatitic rocks are typically low in Barium. Generally, felsic igneous rocks contain more barium than basic rocks, and Alkalic rocks such as syenite contain the highest levels of Barium (upwards of 1600ppm).

The Meguma Supergroup is locally enriched in Ba (Graves and Zentilli, 1988), and the occurrence of alkalic rocks within the C.B.H (Raeside and Barr, 1990; Barr and Jamieson, 1991) also suggests that this region should also have an abundance of Ba, however this is not reflected in the geochemistry of the moose teeth, as the control area shows significantly higher concentrations against the study area.

6.4.2 Lead (Pb)

Lead has an atomic weight of 207.19 and atomic number 82. It is the most abundant of the heavy metals within the earth's crust, about 15ppm by weight, and galena, PbS, is the major lead mineral, but there are a large number of sulphates (about twenty) that are also abundant.

Shale's deposits are where the bulk of sedimentary lead is found at an average concentration of 20 ppm, and concentrations in metamorphic deposits are wholly dependant on the original rock concentration but are generally found in highest concentrations within potassium-rich metamorphic rocks such as mica schists and gneiss.

The Meguma Supergroup is locally enriched with Pb (Graves and Zentilli, 1988), and there are also known sphalerite-bearing marbles that contain minor Pb within the C.B.H (Sangster et al. 1990). The moose teeth from the control area have significantly higher Pb concentrations within their tooth enamel.

6.4.3 Strontium (Sr)

Strontium has an atomic weight of 87.63 and atomic number 38, and is the least abundant of the alkaline earth metals. Strontianite, $SrCO_3$, and celestite, $SrCO_4$, are the main ores for strontium. Calcium and strontium have a strong interaction, as the distribution of Sr within minerals, rocks, sediments and water is affected by the presence of calcium. It is generally found in greatest amounts in calcium rich minerals, and to a lesser extent in potassium rich minerals. Basaltic rocks show a large range of values for strontium, as very little coherence of strontium and calcium is seen. In contrast, granitic rocks show a definite coherence between the two elements, with increasing calcium content implying increasing strontium content. There are regional variations in the Sr content of granitic rocks, as samples from Africa show 160ppm, while the Canadian Shield show values of 305ppm.

Strontium behaviour in sedimentary rocks is almost unpredictable because of the many influences on Sr content in low temperature deposition. Generally, shales, limestones and metamorphic schists do not seem to show strontium coherence with calcium. Strontium contents for various minerals have been determined, and the highest concentrations occur in plagioclases and feldspars, such as monzonites and syenites, with values as high as 1600ppm.

Based on the geology, it is expected that Sr would be in higher concentrations in C.B.H moose teeth as the area is locally abundant with sub-alkalic to alkalic rocks (Raeside and Barr, 1990; Barr and Jamieson, 1991), this is not the case however. Moose teeth enamel from the control area show significantly higher levels of Sr.

However, the behaviour of Sr in sedimentary stages is almost unpredictable according to Fairbridge (1972) and many factors, which are beyond the scope of this thesis, may affect the Sr content of rocks.

6.4.4 Cobalt (Co)

Cobalt has an atomic weight of 58.9332 and atomic number 27. It is a hard bluish white metal and Co^{59} is the only known stable nuclide to exist in nature. The bulk of Cobalt is found within pyroxenes and olivines, with greatest concentrations occurring in sulphide bodies.

Weathering and sedimentation of cobalt displays no marked differentiation, as the simple trivalent state is unstable in water yet reduzate sediments concentrate cobalt due to precipitation of insoluble sulphides. Shales exhibit a mean concentration of cobalt that is similar to the crust of the earth, 25ppm.

One would expect Co to be in higher concentrations in the moose teeth enamel from the C.B.H due to the presence of sulphide deposits (Sangster et al. 1990) where one would expect locally enriched Co occurrences. This is not the case, as the control area shows significantly higher concentrations of Co compared to the study area.

6.4.5 Tin (Sn)

Tin has an atomic weight of 118.69 and atomic number 50. Tin has 10 stable isotopes in nature, the largest of any element, yet is relatively rare in the earth's crust. It is generally associated in granites, but is rather enigmatic as it is quite abundant in some places, but extremely rare in others. The most common mineral by far is the oxide, cassiterite. Cassiterite is the main tin-forming mineral and because of durability it is generally found in weathered areas as saprolites and placer accumulations.

Tin does not readily associate with other elements, so the list of possible minerals is short, however it can replace iron, scandium and titanium.

One would expect tin to be higher in concentration within the teeth of the control area compared to the C.B.H due to the cassiterite deposits, and this is case

6.5 Conclusions

Based on the literature, interpretations are somewhat confusing. Barium and Strontium are usually to be found in highest concentrations within Alkalic rocks such as monzonites and syenites, in concentrations upwards of 1600ppm. The Blair river Complex and Aspy Terrane are both alkalic-subalkalic in composition (Barr et al. 1987; Barr and Jamieson, 1991), and these two units form the majority of land area in the C.B.H (Figure 6.1).

Areas in southwest Nova Scotia are considered to be enriched in Barium, amongst others (Graves and Zentilli, 1988), and due to a close geochemical relationship with Sr, it would be expected that Sr would also be enriched.

However, due to the unpredictable nature of Sr and the high variations associated with this element, further investigation is required.

Cobalt would be expected to be in higher concentrations in the C.B.H due to the parent rock present, but as Sangster et al. (1990) concluded, minor elements commonly associated with base metal sulphide deposits, including Ag, Au, Sb, *Co*, Ni, and Mo are low compared to similar rock types of the Grenville Supergroup.

Due to the locality of the East Kemptville mine that occurs in close proximity with the control area, and also knowing that tin is relatively rare other than being abundant in cassiterite, there is a strong correlation between the tin concentrations within moose teeth enamel and the regional geology of the geographic locality of moose origin. Based on these results for tin, Ba, Sr, and Co it is possible to determine the geographic origin of a moose.

6.6 Summary of Chapter

Sangster et al (1990) concluded that marble-hosted zinc occurrences at Lime Hill and Meat Cove within the C.B.H were anomalously low in Ag, Au, Sb, Co, Ni, and Mo compared the zinc occurrences hosted by Grenville supergroup marble in Ontario, Quebec and New York, which is considered geologically, geochemically, and isotopically (S and Pb) similar to occurrences within the C.B.H.

Southwest N.S is known for the East Kemptville cassiterite deposit, North Americas only producing primary tin mine East Kemptville, situated in close proximity to the control area, was for a while North Americas only producing primary tin mine, with a cassiterite (Tin Oxide) deposit of 58 million tonnes (0.165% tin) (Richardson et al., 1988).

Manganiferous calcareous argillite and black slate at the base of the Halifax Formation are preferentially enriched in Mn, total C, Ba, Pb, Co, Zn, Cu, Mo, W and Au over average crustal values and over lithologies of the Goldenville Halifax transition zone (GHT) (Graves and Zentilli, 1988).

Generally, felsic igneous rocks contain more barium than basic rocks, and Alkalic rocks such as syenite contain the highest levels of Barium (upwards of 1600ppm).

Sr is generally found in greatest amounts in calcium rich minerals, and to a lesser extent in potassium rich minerals. Strontium contents for various minerals have been determined, and the highest concentrations occur in plagioclases and feldspars, such as monzonites and syenites, with values as high as 1600ppm.

Based on these results for tin, Ba, Sr, and Co it is possible to determine the geographic origin of a moose.

Chapter 7: Conclusions and Recommendations for Future Work.

7.1 Conclusions

- Moose require trace elements in small amounts, although little is known about trace element benefits/requirements in moose. These minerals are obtained from the forage that moose ingest, and the forage will vary geographically as moose are inclined to sample new plants that they encounter.
- Moose require a variety of plant species in order to obtain their nutritional requirements, and are therefore considered a 'generalist' browser. This forage must be highly palatable for the moose, and must contain optimum levels of various nutrient and mineral components. Actively growing plant tissues represent the highest quality foods available to moose.
- Increased bark stripping amongst C.B.H moose has been observed, and this behaviour usually occurs when areas support poor winter browse, when food is in short supply in late winter when preferred foods are unavailable or when animals are restricted by deep snow cover. It is increasingly evident in areas of C.B.H that support high-density moose populations where heavy browsing of preferred vegetation is evident.
- Bark stripping is not a common behaviour for moose, and is very rarely observed within populations. It is referred to as being a 'starvation' (last resort) food and does not normally comprise a large portion of a moose's diet.
- Bark stripping has implications on moose vitality, as it is important for moose to have a variety of high quality forage in their diet. Bark stripping is suggestive of moose feeding on few plant species, and this will increase the risk of becoming deficient/toxic of trace elements because certain plant species may hyperaccumulate trace elements or may not readily absorb trace elements into the tissue. It is important to

feed on a wide spectrum of plants to obtain essential nutrients not only in sufficient amounts but also in physiologically balanced proportions.

- Osteophagia has also been observed within the C.B.H population, which is triggered by a deficiency of phosphorous. It appears to be the first documented case of osteophagia in moose. This phenomenon occurs in natural conditions and has a distinct geographical distribution that is dependant on the parent rock in which the plants are growing which may be deficient in phosphorous. It may also be influenced by excessive concentrations of Ca, Al or Fe, which can reduce phosphorous availability of to plants.
- Geochemical analysis of the antlers generally shows a higher concentration of Ca/P ratio and Mn within the chewed C.B.H antler. The unchewed, control, antler generally shows higher concentrations of C Ba and K
- Barium, Lead, Strontium, Cobalt and Tin are significantly depleted within the tooth enamel of C.B.H moose compared to that of the control population.
- It has been demonstrated that the omission of Ba and Sr from the diet may result in depressed growth and reduced calcification of bones and teeth in rats and Guinea Pigs.
- The dietary benefits of cobalt have been known for decades. Co has a relationship with vitamin B_{12} synthesis, and Co deficient animals lack the ability to synthesize vitamin B_{12} properly. Symptoms usually include a gradual loss of appetite and failure of growth or loss of body weight, and in some animals there is evidence of hypoplasia within erythrogenic tissues and in bone marrow (Underwood, 1971)
- Hypoplasia in enamel is well documented, and is a defect that results in a lesser quantity of enamel covering the dentin that would normally be present that occurs during matrix formation
- Excessive lead toxicity has been well documented over the years, with symptoms that include anaemia, and neuropathy or encephalopathy

(Underwood, 1971). Yet, the possibility that lead in low concentrations performing some essential biochemical function cannot be excluded

- The weakening of the teeth in the C.B.H may be a result of poor calcification, which ultimately affects the crystal structure within the enamel framework, and also hypoplasia, which is a defect resulting in the enamel being insufficiently represented in teeth that are affected causing enamel to become weak and vulnerable to caries, and possibly fractures.
- In dentistry, the term 'cracks' was originally used to describe narrow, fissurelike structures that are seen in almost all enamel surfaces. It has since been demonstrated that these 'cracks' are in fact dental lamellae, thin, leaflike structures that extend from the enamel surface toward the dentino-enamel junction (DEJ).
- Lamellae consist of organic material with little mineral content. It has been suggested that enamel lamellae may be a site of weakness in a tooth.
- During cavity preparation, dentists are aware of the tendency of enamel to fracture along cleavage planes paralleling the course of the enamel rods (Avery, 1994).
- Type 1 – 5 microfractures described by Graves and Casey (2002, unpublished) are most likely to have been misinterpreted as being enamel lamellae. Based on descriptions by Bhaskar (1991), the microfractures show very close resemblance to enamel lamellae. They occur in all the teeth analysed (Healthy and unhealthy), and the fracturing begins at the enamel surface, and extends towards the DEJ, with type 4 involving the dentin. The fractures are fairly evenly spaced. The longer fractures, such as type 4, are noticeably wider than smaller fractures, such as type 1 fractures.

- Type A and Type B fracturing are of significance. These fracture types are only present within the C.B.H populations. Due to the nature of the fracturing, it appears that these samples are more brittle, allowing for fracturing to occur in any direction.
- The SEM images provide high resolution, high magnification images of the enamel structure. The fracturing present cannot be ruled out as being a result of the preparation of the slide, which required a polished surface for the microprobe, as it is established that enamel does have a tendency to fracture along the cleavage planes that parallel the enamel rods (Avery, 1994). It is interesting to note, however, that there appears to be a higher incidence of fracturing having occurred within the unhealthy teeth, than with the healthy teeth. Although, the frequency of the fracturing seen in the SEM images was higher within the C.B.H teeth, suggesting C.B.H teeth are more brittle compared to the control.
- The microprobe data was slightly useful. There was no indication for the elements that were analysed being depleted/elevated within the study area compared to the control population, although there were interesting trends observed across the enamel structure.
- The geology of the Cape Breton Highlands (C.B.H's) is composed of a complex assemblage of units
- The Blair River complex is composed of a distinctive assemblage of basement rocks including felsic and mafic gneisses, monzodiorite, anorthosite, and syentite.
- The Aspy Terrane include interlayered mafic and felsic metavolcanic rocks and metasedimentary rock s of Ordovician to Silurian age. Both mafic, felsic and intermediate rocks within the Aspy Terrane are all subalkalic.

- The Bras d'Or Terrane includes low pressure, amphibolite-facies, with locally migmatic, and gneissic 'basement. Large areas of mainly greenschists-facies quartzite, marble, and meta-greywacke, and a large volume of Late Precambrian subduction zone-related dioritic, tonalitic, granodioitic, and granitic plutons are also present.
- The Meguma Supergroup consists of thick metamorphosed siliclastic sequences, and is subdivided into two groups: Goldenville Formation and the overlying Halifax Formation, also referred to as the Goldenville-Halifax Transition (GHT) zone (Graves and Zentilli, 1988)
- The Halifax Formation are preferentially enriched in Mn, total C, Ba, Pb, Zn, Cu, Mo, W and Au (Graves and Zentilli, 1988)
- The area is also known for the East Kemptville cassiterite deposit, which was once North Americas only producing primary tin mine
- Barium and Strontium are usually to be found in highest concentrations within Alkalic rocks such as monzonites and syenites, in concentrations upwards of 1600ppm. The Blair river Complex and Aspy Terrane are both alkalic-subalkalic in composition (Barr et al. 1987; Barr and Jamieson, 1991), and these two units form the majority of land area in the C.B.H
- Areas in southwest Nova Scotia are considered to be enriched in Barium, amongst others (Graves and Zentilli, 1988), and due to a close geochemical relationship with Sr, it would be expected that Sr would also be enriched. However, due to the unpredictable nature of Sr and the high variations associated with this element, further investigation is required.
- Due to the locality of the East Kemptville mine that occurs in close proximity with the control area, and also knowing that tin is relatively rare other than being abundant in cassiterite, there is a strong correlation between the tin concentrations within moose teeth enamel and the regional geology of the geographic locality of moose origin.

- Based on these results for tin, it is possible to determine the geographic origin of a moose.

7.2 Recommendations for Future Work

- This thesis is based on the assumption of the control area being a 'healthy' population. Due to there being little/no data in the literature regarding biological values for trace elements for moose, further investigation is required, with larger sampling criteria and also the use of more control populations to verify results. It is recommended that moose teeth samples from Newfoundland be included in any further work, due to the similarities of the regional geology between the C.B.H and areas of Newfoundland, where there is no documentation of similar problems with incisoform breakage within Newfoundland moose.
- Complete studies on moose browse specific to C.B.H. would be required. Moose will sample new plant species when they encounter them, so diets will vary geographically. Biogeochemical analysis of moose forage may further enhance understanding of the problem.
- Preliminary results of moose antler geochemistry suggest higher Ca/P ratios within C.B.H antlers. Further investigation is required, with a larger sample size.
- Results for Ba and Sr are unclear, and require further investigation. Sr in animal tissue is a reflection of the concentrations found within drinking water supplies, therefore investigation of weathering rates of elements may be required, as this may be a contributing factor to the depleted levels of certain elements within the moose of the C.B.H
- Enamel lamellae consist of organic material with little mineral content. It has been suggested that enamel lamellae may be a site of weakness in a tooth. It should be investigated whether lamellae occur in higher frequency within the C.B.H moose teeth than control areas.

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Appendix A: ICP-MS Results for tooth enamel

GEO LABS
GEOSCIENCE LABORATORIES

CERTIFICATE OF ANALYSIS

GL JOB#: 03-0375
CLIENT: Zentilli
DATE:
Method: Custom Analysis

Certified Reference Materials

Lab ID	Element / Client ID	Sample Mass (mg)	Li ppb	Be ppb	Mg ppb	Al ppb	Si ppb	Ca ppb	Sc ppb	Ti ppb	V ppb	Cr ppb	Mn ppb	Fe ppb	Co ppb	Ni ppb	Cu ppb
Matrix Matched NRC Water																	
SLRS-4	Measured Values		0.602	0.0648	1,770	63.1	2,120	71,400	1.00	1.87	0.458	0.313	3.54	102	0.0270	N.D.	1.82
(+60ppm Ca & 0.2% HCl)			0.582	0.0520	1,740	60.6	2,050	68,900	1.04	1.92	0.400	0.257	3.48	105	0.0174	N.D.	1.75
	Reference Values		0.54 ± 0.14	0.007 ± 0.002	1600 ± 100	54 ± 4	1,864 ± 96	*66,200*		1.48 ± 0.16	0.32 ± 0.03	0.33 ± 0.02	3.37 ± 0.18	103 ± 5	0.033 ± 0.006	0.67 ± 0.08	1.81 ± 0.08

Lab ID	Element / Client ID	Sample Mass (mg)	Li ppm	Be ppm	Mg ppm	Al ppm	Si ppm	Ca wt%	Sc ppm	Ti ppm	V ppm	Cr ppm	Mn ppm	Fe ppm	Co ppm	Ni ppm	Cu ppm
Apatite																	
CTA-AC-1	Measured Values	98	1.40	0.301	502	3,110	10,700	34.5	4.92	910	97.7	1.67	355	4,960	1.93	N.D.	40.8
	Reference Values				*435*	*4100*	5700 ± 1300	32.7 ± 3.1	0.244 ± 0.035	2927 ± 554	104 ± 10	*13*	317 ± 50	*5000*	2.72 ± 0.28	*9*	54 ± 4.5
Phosphate Rock																	
BCR-32	Measured Values	101	1.67	1.97	2,260	1,780	5,530	34.2	11.1	187	128	217	15.1	1,460	0.359	26.5	29.3
	Reference Values				2412 ± 60	2911 ± 32	9770 ± 560	36.9 ± 0.2		171 ± 10	153 ± 7	257 ± 16	18.8 ± 1.3	1608 ± 70	0.59 ± 0.06	34.6 ± 1.9	33.7 ± 1.4

Bold: Recommended values
Italic: Information values

Total Procedural Blanks

Samples Lab ID	Element / Client ID	Sample Mass (mg)	Li ppm	Be ppm	Mg ppm	Al ppm	Si ppm	Ca wt%	Sc ppm	Ti ppm	V ppm	Cr ppm	Mn ppm	Fe ppm	Co ppm	Ni ppm	Cu ppm
RBlank-1		100	0.0205	0.00400	10.4	4.94	272	0.0348	0.262	0.188	0.224	N.D.	0.0320	1.46	0.0120	0.0325	0.651
RBlank-2		100	0.0115	0.0400	4.87	7.61	277	0.0277	0.277	0.314	0.474	0.146	0.0860	5.07	0.0125	0.0460	4.90
RBlank-3		100	0.00550	0.0200	2.16	6.69	263	0.00601	0.266	0.191	0.641	0.0585	N.D.	2.45	0.00650	N.D.	0.424

Samples Lab ID	Element / Client ID	Sample Mass (mg)	Li ppm	Be ppm	Mg ppm	Al ppm	Si ppm	Ca wt%	Sc ppm	Ti ppm	V ppm	Cr ppm	Mn ppm	Fe ppm	Co ppm	Ni ppm	Cu ppm
03-0375-01	M003	48	0.533	N.D.	4,440	22.7	552	35.8	1.74	153	0.631	0.129	35.1	121	N.D.	N.D.	48.5
03-0375-02	M010	98	0.653	0.00765	3,740	144	250	35.1	1.33	126	0.429	0.314	47.9	96.0	N.D.	N.D.	41.0
03-0375-03	M023	103	0.389	0.0257	2,770	19.3	144	31.4	1.24	101	0.347	0.159	31.7	126	N.D.	N.D.	21.3
03-0375-04	M038	95	0.401	0.0200	2,790	57.9	194	36.1	1.34	98.5	0.478	0.175	26.1	213	N.D.	N.D.	12.1
03-0375-05	M017	116	1.77	0.00819	2,780	20.1	93.0	30.4	1.12	76.0	0.268	N.D.	113	78.5	N.D.	N.D.	7.97
03-0375-06	M032	103	1.71	0.00243	3,020	13.0	108	29.6	1.11	72.7	0.167	N.D.	46.2	133	N.D.	N.D.	28.3
03-0375-07	M022	88	17.3	0.0210	2,830	31.6	135	36.3	1.36	87.7	0.236	N.D.	30.3	99.5	N.D.	N.D.	28.1
03-0375-08	M030	110	1.49	0.00318	3,960	119	119	35.4	1.34	88.8	0.243	0.0341	103	82.8	N.D.	N.D.	12.4
	Rep. Soln. Analysis	110	1.39	0.0123	3,970	122	72.2	35.2	1.38	70.0	0.209	0.00818	101	81.9	N.D.	N.D.	12.1
03-0375-09	M001	120	2.12	0.0142	3,400	32.3	130	35.1	1.30	77.5	0.187	N.D.	118	85.1	N.D.	N.D.	13.3
03-0375-10	M009	56	1.01	0.0161	2,640	24.8	128	34.4	1.39	74.0	0.982	1.40	39.3	1,600	N.D.	N.D.	19.8
03-0375-11	M012	129	0.488	0.00233	2,680	22.8	98.5	38.5	1.38	84.7	0.168	N.D.	29.3	41.7	N.D.	N.D.	9.09
03-0375-12	M005	122	1.59	0.0135	2,790	329	195	33.8	1.28	78.0	0.316	0.323	52.4	97.2	N.D.	N.D.	31.5
03-0375-13	M006	117	0.676	0.0145	3,200	18.3	113	35.9	1.32	76.6	0.230	N.D.	30.5	118	N.D.	N.D.	9.93
03-0375-14	M016	116	0.524	0.0142	3,290	17.7	62.2	35.2	1.21	84.0	0.309	N.D.	31.5	59.9	0.0513	N.D.	7.80
03-0375-15	M018	116	0.611	0.0147	2,650	52.5	141	36.8	1.41	79.1	0.432	0.185	52.6	152	N.D.	N.D.	19.9
03-0375-16	M008	139	0.306	0.0176	3,160	22.3	86.8	34.7	1.23	75.3	0.183	N.D.	39.6	54.8	N.D.	N.D.	4.92
03-0375-17	M020	95	0.234	0.0168	3,210	16.6	104	33.6	1.24	71.7	0.348	0.00737	12.3	50.2	N.D.	N.D.	15.1
03-0375-18	M011	83	1.66	0.0343	4,720	162	369	32.8	1.52	114	0.729	0.175	51.5	914	0.297	N.D.	16.8
03-0375-19	M041	139	0.485	0.0115	4,220	12.9	92.9	33.9	1.26	80.0	0.354	N.D.	14.4	44.9	N.D.	N.D.	5.42
03-0375-20	M027	82	0.930	0.0317	3,900	139	287	35.7	1.46	80.4	0.497	N.D.	111	162	N.D.	N.D.	8.44
03-0375-21	M037	106	3.16	0.0104	4,460	34.2	111	33.8	1.33	70.0	0.365	N.D.	58.4	47.3	N.D.	N.D.	5.51
03-0375-22	M042	105	0.858	0.0143	4,020	30.1	147	35.2	1.41	70.1	0.320	N.D.	168	111	N.D.	N.D.	9.31
03-0375-23	M051	44	1.81	N.D.	2,860	60.6	137	33.9	1.48	77.2	0.824	0.150	65.0	211	0.903	N.D.	26.0
03-0375-24	M052	91	0.466	0.0220	3,490	80.0	139	32.4	1.33	97.4	0.481	0.107	54.0	361	1.05	N.D.	16.2
03-0375-25	M053	87	1.17	0.0448	2,660	59.9	144	34.5	1.39	70.9	0.555	0.103	38.7	205	N.D.	N.D.	24.3
03-0375-26	M055	81	0.902	0.0426	2,960	95.8	179	35.3	1.37	92.2	0.654	0.370	19.6	639	0.882	N.D.	28.7
03-0375-27	M058	117	0.981	0.0269	2,590	73.1	148	37.2	1.46	97.9	0.353	0.0957	14.7	176	1.51	N.D.	18.1

Duplicate Analyses

Samples Lab ID	Element / Client ID	Sample Mass (mg)	Li ppm	Be ppm	Mg ppm	Al ppm	Si ppm	Ca wt%	Sc ppm	Ti ppm	V ppm	Cr ppm	Mn ppm	Fe ppm	Co ppm	Ni ppm	Cu ppm
03-0375-5D	M017	135	1.96	0.0133	3,000	23.6	81.2	31.1	1.20	61.7	0.151	0.261	117	105	N.D.	N.D.	2.90
	Absolute Difference		0.19	0.0051	220	3.5	-11.8	0.7	0.08	-14.3	-0.117	0.261	4	27			-5.07
	% Difference		11%	62%	8%	17%	-13%	2%	7%	-19%	-44%	100%	4%	34%			-64%
03-0375-21D	M037	67	2.82	0.0299	4,130	41.9	105	31.9	1.36	56.7	0.310	1.04	58.6	178	N.D.	N.D.	7.14
	Absolute Difference		-0.34	0.0195	-330	7.7	-6	-1.9	0.03	-13.3	-0.055	1.04	0.2	131			1.63
	% Difference		-11%	188%	-7%	23%	-5%	-6%	2%	-19%	-15%	100%	0%	277%			30%

A-1

GEO LABS
GEOSCIENCE LABORATORIES

CERTIFICATE OF ANALYSIS

GL JOB#: 03-0375
CLIENT: Zentilli
DATE:
Method: Custom Analysis

Certified Reference Materials

Lab ID	Element / Client ID	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce
		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Matrix Matched NRC Water																		
SLRS-4	Measured Values	1.25	0.0219	2.95	1.62	31.5	0.151	0.110	0.00730	0.277	0.00520	0.0475	0.00870	0.276	0.00700	12.9	0.298	0.397
(+60ppm Ca & 0.2% HCl)		1.23	0.0225	2.96	1.62	31.7	0.149	0.111	0.00960	0.270	0.00780	0.0493	0.0100	0.279	0.00800	12.7	0.305	0.403
	Reference Values	**0.93 ± 0.1**	*0.0119 ± 0.0008*	**0.68 ± 0.06**	*1.53 ± 0.1*	**26.3 ± 3.2**	*0.146 ± 0.016*	*0.12 ± 0.03*		**0.21 ± 0.02**	*0.035 ± 0.01*	**0.012 ± 0.002**		**0.23 ± 0.04**	*0.009 ± 0.002*	**12.2 ± 0.6**	*0.287 ± 0.016*	*0.36 ± 0.024*
Lab ID	Element / Client ID	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Apatite																		
CTA-AC-1	Measured Values	20.8	23.5	9.32	10.9	16,500	295	10.5	7.28	1.30	0.0939	0.237	0.405	0.246	0.261	795	1,550	2,410
	Reference Values	38 ± 7.6				*20000*	272 ± 53	*57*								767 ± 79	2176 ± 94	3226 ± 175
Phosphate Rock																		
BCR-32	Measured Values	209	1.75	10.3	3.11	904	245	22.3	0.439	2.80	0.979	19.6	0.353	2.75	0.240	98.9	93.9	29.8
	Reference Values	253 ± 6		9.5 ± 0.5						*24*	*2*	20.8 ± 0.7		*3*				

Bold: Recommended values
Italic: Information values

Total Procedural Blanks

Samples / Lab ID	Element / Client ID	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
RBlank-1		1.44	0.0355	3.28	0.0180	0.381	0.0105	0.00650	0.00800	0.0125	0.0100	0.0110	0.00650	0.0115	0.00700	0.147	0.00950	0.0110
RBlank-2		9.30	0.0320	3.09	0.0155	2.08	0.0555	0.00350	0.00350	0.0275	0.0100	0.0260	0.00900	0.0100	0.00300	0.450	0.168	0.247
RBlank-3		1.47	0.0385	3.38	0.0100	0.140	0.00550	0.113	0.00250	0.0220	0.00550	0.0120	N.D.	0.00700	0.00350	0.0555	0.00300	0.00450

Samples / Lab ID	Element / Client ID	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
03-0375-01	M003	70.3	0.267	8.06	0.335	243	0.0438	0.0427	0.0135	0.0448	0.294	0.0865	0.0438	0.141	0.00417	122	0.0781	0.0438
03-0375-02	M010	74.4	0.229	5.08	0.403	268	0.0474	0.0755	0.0163	0.0500	0.0730	0.107	0.0974	0.0245	0.00408	121	0.0801	0.0286
03-0375-03	M023	43.7	0.220	3.87	0.287	239	0.0417	0.0364	0.0102	0.0306	0.114	0.165	0.0286	0.0126	0.00194	128	0.0689	0.0199
03-0375-04	M038	47.8	0.226	5.01	0.554	226	0.0495	3.35	0.0137	0.106	0.0426	0.0284	0.0374	0.0353	0.00316	82.1	0.114	0.120
03-0375-05	M017	48.5	0.166	3.83	0.688	255	0.0435	0.0897	0.00905	0.0237	0.0142	0.0746	0.0573	0.0134	0.00216	161	0.0810	0.0246
03-0375-06	M032	47.2	0.199	4.22	0.917	249	0.0354	0.140	0.00971	0.0209	0.0257	0.243	0.0223	0.0117	0.00340	159	0.0738	0.0126
03-0375-07	M022	45.5	0.242	5.11	0.326	280	0.0483	0.0358	0.0222	0.0335	0.0722	0.240	0.0494	0.0273	0.00398	147	0.0756	0.0239
03-0375-08	M030	79.4	0.192	4.58	0.390	293	0.0541	1.31	0.0100	0.0245	0.0227	0.0714	0.0491	0.0227	0.00273	164	0.0905	0.0300
	Rep. Soln. Analysis	77.9	0.160	4.42	0.420	285	0.0636	1.40	0.0127	0.0236	0.0295	0.0695	0.0500	0.0177	0.00318	163	0.0964	0.0314
03-0375-09	M001	49.2	0.220	4.14	0.725	246	0.0504	0.0363	0.0133	0.0613	0.0342	0.0683	0.0454	0.0813	0.00292	96.4	0.0638	0.0392
03-0375-10	M009	45.8	0.238	6.37	0.331	313	0.0455	1.68	0.104	0.102	0.104	0.0491	0.168	0.0241	0.00357	118	0.0661	0.0107
03-0375-11	M012	45.3	0.234	4.56	0.480	338	0.0725	0.0570	0.0132	0.0279	0.0159	0.640	0.0736	0.0120	0.00310	120	0.0705	0.0446
03-0375-12	M005	68.0	0.234	3.97	0.682	193	0.0516	0.0730	0.0193	0.0459	0.0266	0.100	0.144	0.0123	0.00574	118	0.0881	0.0549
03-0375-13	M006	49.9	0.204	4.55	0.608	360	0.0654	0.0346	0.0141	0.0154	0.0261	0.0538	0.171	0.00855	0.00256	176	0.128	0.0765
03-0375-14	M016	38.5	0.200	4.67	0.757	199	0.0302	1.28	0.0108	0.0276	0.0595	0.0388	0.0284	0.00388	0.00259	81.5	0.0397	0.0112
03-0375-15	M018	48.8	0.228	4.70	0.533	192	0.0414	0.0513	0.0177	0.242	0.0703	0.0612	0.199	0.0147	0.00474	72.6	0.0543	0.0384
03-0375-16	M008	36.0	0.181	4.12	0.738	285	0.0432	0.0327	0.0122	0.0284	0.0191	0.0396	0.0504	0.00935	0.00360	84.4	0.0486	0.0194
03-0375-17	M020	42.7	0.185	4.91	0.872	278	0.0442	0.0289	0.0147	0.0300	0.0200	0.0579	0.109	0.00684	0.00263	79.8	0.0432	0.0179
03-0375-18	M011	55.1	0.196	5.18	1.25	224	0.190	0.195	0.0349	0.0554	0.0524	6.90	0.322	0.0422	0.0187	110	0.139	0.143
03-0375-19	M041	37.9	0.144	4.02	0.585	278	0.0471	0.640	0.0140	0.0270	0.0144	0.0342	0.0295	0.0151	0.00396	115	0.0680	0.0212
03-0375-20	M027	85.9	0.201	5.53	0.908	290	0.0774	0.0274	0.0201	0.0287	0.0238	0.0329	0.0207	0.0213	0.0171	151	0.153	0.160
03-0375-21	M037	49.2	0.145	4.47	0.570	236	0.0462	0.0269	0.0127	0.0208	0.0108	0.0646	0.0108	0.0104	0.00425	114	0.101	0.0769
03-0375-22	M042	72.5	0.158	4.43	0.809	415	0.153	0.0295	0.0190	0.108	0.0143	0.121	0.0452	0.0100	0.00381	235	0.687	0.941
03-0375-23	M051	80.3	0.172	7.37	0.689	490	0.169	0.0273	0.0216	0.0659	0.0739	0.201	0.151	0.0477	0.00568	171	0.660	0.916
03-0375-24	M052	60.6	0.162	4.31	0.521	267	0.123	0.0374	0.0214	0.0214	0.0407	0.430	0.336	0.0192	0.00604	285	0.345	0.326
03-0375-25	M053	62.1	0.144	5.29	0.926	474	0.0966	3.27	0.0149	0.0557	0.0494	0.292	0.0287	0.00747	0.00920	172	0.176	0.180
03-0375-26	M055	53.6	0.177	5.37	0.891	546	0.164	0.0778	0.0228	0.0759	0.0889	0.717	0.449	0.0185	0.00988	200	0.236	0.256
03-0375-27	M056	62.2	0.173	4.71	0.891	564	0.101	0.0842	0.0214	0.0470	0.0380	0.241	0.744	0.0299	0.00684	179	0.121	0.0816

Duplicate Analyses

Samples / Lab ID	Element / Client ID	Zn	Ga	As	Rb	Sr	Y	Zr	Nb	Mo	Ag	Cd	Sn	Sb	Cs	Ba	La	Ce
		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
03-0375-5D	M017	44.1	0.122	3.81	0.721	268	0.0452	2.21	0.00926	0.0993	0.0170	0.0778	0.0437	0.00815	0.00333	167	0.0915	0.0285
	Absolute Difference	-4.4	-0.044	-0.02	0.033	13	0.0017	2.12	0.00021	0.0756	0.0028	0.0032	-0.0136	-0.00525	0.00117	6	0.0105	0.0039
	% Difference	-9%	-27%	-1%	5%	5%	4%	2363%	2%	319%	20%	4%	-24%	-39%	54%	4%	13%	16%
03-0375-21D	M037	63.3	0.176	5.88	0.593	228	0.0440	0.0769	0.0157	0.0634	0.0224	0.149	0.0806	0.0478	0.00448	109	0.0716	0.0358
	Absolute Difference	14.1	0.031	1.41	0.023	-8	-0.0022	0.0500	0.0030	0.0426	0.0116	0.084	0.0698	0.0374	0.00023	-5	-0.0294	-0.0411
	% Difference	29%	21%	32%	4%	-3%	-5%	186%	24%	205%	107%	130%	646%	360%	5%	-4%	-29%	-53%

GEO LABS
GEOSCIENCE LABORATORIES

CERTIFICATE OF ANALYSIS

GL JOB#: 03-0375
CLIENT: Zentilli
DATE:
Method: Custom Analysis

Certified Reference Materials

Lab ID	Element / Client ID	Pr ppb	Nd ppb	Sm ppb	Eu ppb	Tb ppb	Gd ppb	Dy ppb	Ho ppb	Er ppb	Tm ppb	Yb ppb	Lu ppb	Hf ppb	Ta ppb
Matrix Matched NRC Water															
SLRS-4	Measured Values	0.0707	0.273	0.0595	0.00840	0.00490	0.0387	0.0263	0.00690	0.0138	0.00230	0.0140	0.00200	0.00370	0.000900
(+60ppm Ca & 0.2% HCl)		0.0713	0.276	0.0582	0.00970	0.00540	0.0365	0.0260	0.00870	0.0149	0.00340	0.0123	0.00350	0.00400	0.00250
	Reference Values	0.0693 ± 0.0036	0.269 ± 0.028	0.0574 ± 0.0056	0.0080 ± 0.0012	0.0043 ± 0.0008	0.0342 ± 0.004	0.0242 ± 0.0032	0.0047 ± 0.0006	0.0134 ± 0.0012	0.0017 ± 0.0004	0.0120 ± 0.0008	0.0019 ± 0.0002		

Lab ID	Element / Client ID	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Gd ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm
Apatite															
CTA-AC-1	Measured Values	320	1,110	158	44.0	13.4	151	67.4	10.8	23.5	2.36	9.20	1.15	0.549	0.134
	Reference Values	*357*	1087 ± 124	162 ± 24	46.7 ± 1.3	13.9 ± 1.5	124 ± 23	*78*	*9*	*26*		11.4 ± 2.0	1.08 ± 0.16	1.13 ± 0.17	2.65 ± 0.23
Phosphate Rock															
BCR-32	Measured Values	13.9	61.1	12.2	3.28	2.61	18.6	18.6	4.70	15.0	2.17	13.9	2.39	0.324	0.0728
	Reference Values														

Bold: Recommended values
Italic: Information values

Total Procedural Blanks

Samples Lab ID	Element Client ID	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Gd ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm
RBlank-1		0.00750	0.0170	0.0130	0.00800	0.00700	0.0105	0.0105	0.00850	0.0100	0.00750	0.00950	0.0100	0.00500	0.00850
RBlank-2		0.0300	0.100	0.0120	0.00550	0.00450	0.0215	0.0105	0.00450	0.00800	0.00300	0.00450	0.00350	0.00350	0.00350
RBlank-3		0.00350	0.00300	0.00250	0.00350	0.00300	0.00350	0.00500	0.00300	0.00500	0.00350	0.00500	0.00300	0.00400	0.00200

Samples Lab ID	Element Client ID	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Gd ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm
03-0375-01	M003	0.00313	0.0167	0.00417	0.00417	0.00208	0.0146	0.00938	0.00208	0.00625	0.00313	0.00521	0.00208	0.00729	0.00313
03-0375-02	M010	0.00510	0.0143	0.00612	0.00612	0.00255	0.00561	0.00306	0.00102	0.00306	0.000510	0.00306	0.000510	0.00357	0.00204
03-0375-03	M023	0.00340	0.00971	0.00243	N.D.	0.000971	0.00631	0.00340	0.000971	0.00243	N.D.	0.00291	0.000971	N.D.	0.000971
03-0375-04	M038	0.0121	0.0532	0.00579	N.D.	0.00105	0.00789	0.00474	0.00158	0.00421	N.D.	0.00105	N.D.	0.0721	0.000526
03-0375-05	M017	0.00302	0.00690	0.00259	0.00302	0.000862	0.00302	0.00259	0.000862	0.00172	N.D.	0.00129	0.000431	0.00216	0.000431
03-0375-06	M032	0.00194	0.00922	0.00146	N.D.	0.000485	0.00437	0.00291	N.D.	0.00243	0.000485	0.00194	0.000485	0.00243	0.00146
03-0375-07	M022	0.00284	0.0102	0.00511	0.00341	0.00114	0.00625	0.00511	0.00114	0.00284	0.000568	0.00170	0.000568	0.00170	0.000568
03-0375-08	M030	0.00409	0.0227	0.00636	N.D.	0.000455	0.00909	0.00227	0.000455	0.00227	N.D.	0.000455	N.D.	0.0264	0.000455
	Rep. Soln. Analysis	0.00591	0.0118	0.00273	N.D.	0.00136	0.00955	0.00455	0.000909	0.00182	N.D.	0.00182	0.000455	0.0314	0.000909
03-0375-09	M001	0.00625	0.0188	0.00792	0.00333	0.000417	0.00458	0.00333	0.000417	0.00208	0.000417	0.00208	0.000417	0.00167	N.D.
03-0375-10	M009	0.000893	0.00625	N.D.	N.D.	0.000893	0.00625	0.00179	N.D.	0.00357	N.D.	N.D.	0.000893	0.0268	0.00179
03-0375-11	M012	0.00620	0.0271	0.00698	N.D.	0.000775	0.00271	0.0105	0.00116	0.00349	0.000775	0.00388	0.000775	0.00194	0.000388
03-0375-12	M005	0.00574	0.0221	0.00574	0.00164	0.00164	0.00533	0.00287	0.00123	0.00451	0.000410	0.000820	0.000410	0.00205	0.00123
03-0375-13	M006	0.00897	0.0184	0.00556	N.D.	0.000855	0.00470	0.00299	0.000427	0.00214	N.D.	0.000855	0.000855	0.00342	0.00128
03-0375-14	M016	0.00172	0.0103	0.00345	N.D.	N.D.	0.00302	0.00216	N.D.	0.00216	0.000431	0.00129	0.000431	0.0237	N.D.
03-0375-15	M018	0.00388	0.0220	0.00388	N.D.	N.D.	0.00517	0.00388	0.000862	0.00259	N.D.	0.00172	0.000862	0.00216	0.00129
03-0375-16	M008	0.00288	0.0115	0.00288	0.00468	0.000719	0.00576	0.00324	0.000360	0.00180	0.000360	0.00180	0.000360	0.00216	0.000719
03-0375-17	M020	0.00158	0.00842	0.00316	N.D.	0.000526	0.00632	0.00263	0.000526	0.00158	N.D.	0.00105	0.00105	0.00105	0.000526
03-0375-18	M011	0.0205	0.0813	0.0169	0.00843	0.00783	0.0337	0.0277	0.00964	0.0235	0.00482	0.0235	0.00723	0.00843	0.00783
03-0375-19	M041	0.00360	0.00827	0.00396	N.D.	0.00180	0.00647	0.00324	0.00252	0.00432	0.00180	0.00252	0.00216	0.0151	0.00252
03-0375-20	M027	0.0189	0.0817	0.0140	0.00183	0.00305	0.0128	0.00915	0.00305	0.00610	0.00183	0.00366	0.00183	0.00244	0.00244
03-0375-21	M037	0.00802	0.0340	0.00613	0.00236	0.000943	0.00519	0.00425	0.000943	0.00189	0.000472	0.00189	0.000472	0.000943	0.000472
03-0375-22	M042	0.0919	0.332	0.0414	0.00714	0.00524	0.0529	0.0186	0.00429	0.00905	0.000952	0.00333	0.000952	N.D.	0.000952
03-0375-23	M051	0.0864	0.310	0.0318	0.0170	0.00341	0.0364	0.0239	0.00568	0.00909	0.00114	0.00909	0.00227	0.00682	0.00114
03-0375-24	M052	0.0330	0.131	0.0242	0.0148	0.00220	0.0357	0.0165	0.00275	0.00934	0.000549	0.00604	0.00110	0.00330	0.000549
03-0375-25	M053	0.0190	0.0747	0.0172	N.D.	0.00115	0.0172	0.00805	0.00172	0.00287	N.D.	0.00402	0.000575	0.0603	0.00115
03-0375-26	M055	0.0265	0.0957	0.0198	0.00617	0.00185	0.0265	0.0204	0.00309	0.00926	0.00123	0.00679	0.00123	0.00123	0.000617
03-0375-27	M056	0.00769	0.0338	0.00726	N.D.	0.000855	0.00726	0.00513	0.00128	0.00171	N.D.	0.00214	0.000855	0.00128	N.D.

Duplicate Analyses

Samples Lab ID	Element Client ID	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Gd ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm
03-0375-5D	M017	0.00370	0.0189	0.00407	N.D.	0.000370	0.00296	0.00222	0.00111	0.00111	0.000370	0.00148	0.000741	0.0537	0.000741
	Absolute Difference	0.00068	0.0120	0.00148	0.00302	-0.000492	-0.00006	-0.00037	0.00025	-0.00061	0.000370	0.00019	0.000310	0.0515	0.000310
	% Difference	23%	174%	57%		-57%	-2%	-14%	29%	-35%	100%	15%	72%	2384%	72%
03-0375-21D	M037	0.00373	0.0187	0.0119	0.00149	0.00149	0.00224	0.00149	0.00149	0.00373	N.D.	N.D.	0.000746	0.00299	0.000746
	Absolute Difference	-0.00429	-0.0153	0.0058	-0.00087	0.00055	-0.00295	-0.00276	0.00055	0.00184	0.000472	0.00189	0.000274	0.00205	0.000274
	% Difference	-53%	-45%	95%	-37%	58%	-57%	-65%	58%	97%	100%	100%	58%	217%	58%

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GEO LABS
GEOSCIENCE LABORATORIES

CERTIFICATE OF ANALYSIS

GL JOB#: 03-0375
CLIENT: Zentilli
DATE:
Method: Custom Analysis

Certified Reference Materials

Lab ID	Element / Client ID	W ppb	Tl ppb	Pb ppb	Bi ppb	Th ppb	U ppb
Matrix Matched NRC Water							
SLRS-4	Measured Values	0.0148	0.00690	0.103	0.00600	0.0158	0.0482
(+60ppm Ca & 0.2% HCl)		0.0150	0.00830	0.107	0.00590	0.0163	0.0489
	Reference Values	**0.0133 ± 0.0020**	**0.0076 ± 0.0012**	**0.086 ± 0.007**		**0.018 ± 0.006**	**0.050 ± 0.003**

Lab ID	Element / Client ID	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
Apatite							
CTA-AC-1	Measured Values	0.470	0.00867	3.66	0.00765	21.1	3.86
	Reference Values					21.8 ± 2.1	4.4 ± 0.9
Phosphate Rock							
BCR-32	Measured Values	0.300	0.0960	4.05	0.0173	2.15	112
	Reference Values			*5*		*2*	*125*

Bold: Recommended values
Italic: Information values

Total Procedural Blanks

Samples Lab ID	Element Client ID	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
RBlank-1		0.0170	0.0105	0.0780	0.0150	0.00500	0.00900
RBlank-2		0.0115	0.00300	2.23	0.00650	0.00450	0.0200
RBlank-3		0.00650	0.00400	0.447	0.00650	0.00150	0.00350

Samples Lab ID	Element Client ID	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
03-0375-01	M003	16.9	0.00729	0.958	0.0188	0.00417	0.00208
03-0375-02	M010	20.8	0.00510	0.824	0.0173	0.00255	0.00306
03-0375-03	M023	4.43	0.00534	0.479	0.0150	0.000485	0.00243
03-0375-04	M038	2.47	0.00526	0.665	0.0132	0.00211	0.00263
03-0375-05	M017	2.76	0.0138	0.789	0.0181	0.000862	0.00345
03-0375-06	M032	23.3	0.0136	0.411	0.0316	0.000971	0.000971
03-0375-07	M022	1.77	0.00966	0.677	0.0142	0.00284	0.00227
03-0375-08	M030	2.39	0.00636	0.775	0.0123	0.000909	0.00182
	Rep. Soln. Analysis	2.27	0.00545	0.737	0.0109	0.00136	0.00682
03-0375-09	M001	2.81	0.00542	0.673	0.0150	0.00167	0.00250
03-0375-10	M009	19.1	0.00714	0.774	0.00714	0.000893	0.00179
03-0375-11	M012	3.03	0.00581	0.806	0.0295	0.00116	0.000775
03-0375-12	M005	1.53	0.00533	1.15	0.0115	0.00656	0.00533
03-0375-13	M006	3.04	0.00470	0.608	0.00684	0.00128	0.00171
03-0375-14	M016	0.988	0.00819	0.534	0.00517	0.000862	0.000862
03-0375-15	M018	2.18	0.00603	1.33	0.00819	0.00216	0.00259
03-0375-16	M008	1.74	0.00504	0.519	0.00324	0.000719	0.00108
03-0375-17	M020	39.3	0.00526	0.509	0.0126	0.00105	0.00158
03-0375-18	M011	2.92	0.0151	1.88	0.0584	0.0151	0.0151
03-0375-19	M041	18.0	0.00647	0.330	0.00504	0.00180	0.00324
03-0375-20	M027	2.61	0.0116	0.980	0.00915	0.0104	0.0110
03-0375-21	M037	1.61	0.00708	0.849	0.00849	0.00189	0.00189
03-0375-22	M042	12.2	0.0114	0.702	0.0105	0.0176	0.00333
03-0375-23	M051	8.39	0.00682	3.30	0.0205	0.0182	0.00568
03-0375-24	M052	1.80	0.00879	3.01	0.0242	0.00989	0.00440
03-0375-25	M053	1.88	0.0109	1.06	0.0178	0.00517	0.00460
03-0375-26	M055	3.37	0.00617	1.96	0.0407	0.00988	0.00802
03-0375-27	M056	3.01	0.00726	1.42	0.0171	0.00427	0.00385

Duplicate Analyses

Samples Lab ID	Element Client ID	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
03-0375-5D	M017	2.64	0.0122	0.591	0.0137	0.00111	0.00333
	Absolute Difference	-0.12	-0.0016	-0.198	-0.0044	0.00025	-0.00012
	% Difference	-4%	-12%	-25%	-24%	29%	-3%
03-0375-21D	M037	1.56	0.00821	2.07	0.0149	0.00299	0.00224
	Absolute Difference	-0.05	0.00113	1.22	0.0064	0.00110	0.00035
	% Difference	-3%	16%	144%	75%	58%	19%

Appendix B: one-way ANOVA of variance results: Control (Including Parrsboro), North of the Park, South of the Park

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	5549	2775	0.54	0.590
Error	22	112759	5125		
Total	24	118308			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N      Mean     StDev     ----------+---------+---------+------
Al (H)       5     73.88     14.92       (---------------*----------------)
Al (N)      10     49.10     45.32      (----------*-----------)
Al (S)      10     81.52    101.86              (----------*-----------)
                                       ----------+---------+---------+------
Pooled StDev =     71.59                         40        80       120
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.003070	0.001535	1.97	0.163
Error	22	0.017132	0.000779		
Total	24	0.020202			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N      Mean     StDev     --+---------+---------+---------+----
Sb (H)       5   0.02455   0.01518      (------------*------------)
Sb (N )     10   0.03933   0.04105                  (--------*--------)
Sb (S)      10   0.01465   0.01077     (--------*--------)
                                       --+---------+---------+---------+----
Pooled StDev =   0.02791               0.000     0.020     0.040     0.060
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	22932	11466	**6.71**	0.005
Error	22	37618	1710		
Total	24	60550			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N      Mean     StDev     ------+---------+---------+---------+
Ba (H)       5    201.40     48.17                      (---------*---------)
Ba (N)      10    125.85     25.80      (-----*------)
Ba (S)      10    125.52     49.83      (-----*------)
                                       ------+---------+---------+---------+
Pooled StDev =    41.35                    120       160       200       240
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	1.73	0.86	0.45	0.645
Error	22	42.56	1.93		
Total	24	44.29			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ----+---------+---------+---------+--
Cd (H)       5     0.376     0.209   (-----------------*------------------)
Cd (N)      10     0.161     0.180     (------------*------------)
Cd (S)      10     0.746     2.163            (------------*------------)
                                    ----+---------+---------+---------+--
Pooled StDev =     1.391             -0.70      0.00      0.70      1.40
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.0312	0.0156	1.24	0.310
Error	22	0.2777	0.0126		
Total	24	0.3090			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  -+---------+---------+---------+-----
Cr (H)       5    0.1651    0.1165           (------------*------------)
Cr (N)      10    0.0951    0.1062      (---------*---------)
Cr (S)      10    0.0687    0.1164  (---------*---------)
                                    -+---------+---------+---------+-----
Pooled StDev =    0.1124           0.000     0.080     0.160     0.240
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	601	300	2.92	0.075
Error	22	2260	103		
Total	24	2861			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ---+---------+---------+---------+---
Cu (H)       5     22.66      5.31            (-----------*-----------)
Cu (N)      10     22.37     13.13               (--------*--------)
Cu (S)      10     12.46      8.13  (--------*--------)
                                    ---+---------+---------+---------+---
Pooled StDev =     10.13              8.0      16.0      24.0      32.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     74518     37259     0.29    0.748
Error      22   2792078    126913
Total      24   2866596
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ---+---------+---------+---------+---
Fe (H)      5     318.4     193.2     (----------------*---------------)
Fe (N)     10     257.1     473.9      (-----------*-----------)
Fe (S)     10     175.9     262.8   (-----------*----------)
                                    ---+---------+---------+---------+---
Pooled StDev =    356.2                0       200       400       600
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     7.368     3.684    13.67    0.000
Error      22     5.928     0.269
Total      24    13.296
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -----+---------+---------+---------+-
Pb (H)      5    2.1500    0.9771                      (------*------)
Pb (N)     10    0.7231    0.1334   (----*----)
Pb (S)     10    0.8876    0.4653      (----*----)
                                    -----+---------+---------+---------+-
Pooled StDev =   0.5191                 0.70      1.40      2.10      2.80
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2      14.2       7.1     0.62    0.545
Error      22     250.7      11.4
Total      24     264.9
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -+---------+---------+---------+-----
Li (H)      5     1.066     0.490    (--------------*---------------)
Li (N)     10     2.612     5.197               (----------*----------)
Li (S)     10     1.076     0.863        (----------*----------)
                                    -+---------+---------+---------+-----
Pooled StDev =    3.376            -2.0       0.0       2.0       4.0
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	1515	758	0.53	0.596
Error	22	31445	1429		
Total	24	32961			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev     ---------+---------+---------+-------
Mn (H)       5     38.40     21.60     (-------------*-------------)
Mn (N)      10     54.03     33.68                (---------*---------)
Mn (S)      10     59.63     46.39                  (---------*---------)
                                       ---------+---------+---------+-------
Pooled StDev =     37.81                       25        50        75
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.00049	0.00024	0.10	0.905
Error	22	0.05352	0.00243		
Total	24	0.05401			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev     --------+---------+---------+--------
Mo (H)       5   0.05318   0.02081      (----------------*-----------------)
Mo (N)      10   0.05029   0.03082         (------------*------------)
Mo (S)      10   0.06000   0.06931             (------------*------------)
                                       --------+---------+---------+--------
Pooled StDev =   0.04932                     0.025     0.050     0.075
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.000124	0.000062	0.17	0.843
Error	22	0.007952	0.000361		
Total	24	0.008077			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev     --------+---------+---------+--------
Nb (H)       5   0.02042   0.00314      (---------------*----------------)
Nb (N)      10   0.02258   0.02885            (------------*-----------)
Nb (S)      10   0.01761   0.00686       (------------*-----------)
                                       --------+---------+---------+--------
Pooled StDev =   0.01901                     0.010     0.020     0.030
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.5346    0.2673     7.19    0.004
Error      22    0.8175    0.0372
Total      24    1.3521
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Rb (H)      5    0.7816    0.1726                (--------*--------)
Rb (N)     10    0.4634    0.1780   (-----*-----)
Rb (S)     10    0.7507    0.2142                 (------*-----)
                                   ----+---------+---------+---------+--
Pooled StDev =   0.1928              0.40      0.60      0.80      1.00
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.0046    0.0023     0.11    0.900
Error      22    0.4771    0.0217
Total      24    0.4817
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
Ag (H)      5    0.0582    0.0223  (---------------*----------------)
Ag (N)     10    0.0793    0.0831         (-----------*-----------)
Ag (S)     10    0.0950    0.2142           (-----------*-----------)
                                   ----------+---------+---------+------
Pooled StDev =   0.1473                    0.000     0.080     0.160
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    159844     79922    14.93    0.000
Error      22    117800      5355
Total      24    277644
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
Sr (H)      5    468.20    118.55                   (------*------)
Sr (N)     10    269.80     35.95   (----*----)
Sr (S)     10    266.85     74.50   (----*---)
                                   ---------+---------+---------+-------
Pooled StDev =    73.17                    300       400       500
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	1286	643	1.82	0.185
Error	22	7755	353		
Total	24	9041			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ----+---------+---------+---------+--
Ti (H)       5     87.12     12.34    (--------------*-------------)
Ti (N)      10     96.55     25.21                (---------*----------)
Ti (S)      10     80.57     12.59   (---------*---------)
                                    ----+---------+---------+---------+--
Pooled StDev =     18.78                72        84        96       108
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.1398	0.0699	1.71	0.204
Error	22	0.8994	0.0409		
Total	24	1.0391			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ----+---------+---------+---------+--
V (H)        5    0.5734    0.1780            (-----------*------------)
V (N)       10    0.3918    0.2550   (--------*--------)
V (S)       10    0.3818    0.1443   (-------*--------)
                                    ----+---------+---------+---------+--
Pooled StDev =    0.2022              0.30      0.45      0.60      0.75
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	328	164	0.81	0.459
Error	22	4466	203		
Total	24	4794			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  -----+---------+---------+---------+-
Zn (H)       5     63.76      9.90       (------------*------------)
Zn (N)      10     54.92     13.90   (--------*--------)
Zn (S)      10     54.51     16.11  (---------*--------)
                                    -----+---------+---------+---------+-
Pooled StDev =     14.25                 50        60        70        80
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2  0.000827    0.000414      3.41    0.051
Error      22  0.002669    0.000121
Total      24  0.003497
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev  ------+---------+---------+---------+
Be (H))     5   0.02726     0.01812              (---------*---------)
Be (N)     10   0.01155     0.00901  (-------*------)
Be (S)     10   0.01763     0.00833        (-------*------)
                                     ------+---------+---------+---------+
Pooled StDev =  0.01102                  0.010     0.020     0.030     0.040
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2   1988252      994126      2.51    0.105
Error      22   8727532      396706
Total      24  10715784
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev  ----+---------+---------+---------+--
Mg (H)      5    2912.0       355.8   (----------*-----------)
Mg (N)     10    3215.0       633.2            (-------*--------)
Mg (S)     10    3643.5       715.9                     (--------*-------)
                                     ----+---------+---------+---------+--
Pooled StDev =    629.8                2500      3000      3500      4000
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2      5091        2545      0.22    0.804
Error      22    253995       11545
Total      24    259086
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev  --+---------+---------+---------+----
Si (H)      5     149.4        17.1  (---------------*---------------)
Si (N)     10     185.1       136.8            (-----------*-----------)
Si (S)     10     161.4        96.8       (-----------*-----------)
                                     --+---------+---------+---------+----
Pooled StDev =    107.4               60        120       180       240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2      0.08        0.04      0.01    0.989
Error      22     80.02        3.64
Total      24     80.10
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev --+---------+---------+---------+----
Ca (H)      5    34.660       1.773  (----------------*---------------)
Ca (N)     10    34.810       2.448         (-----------*------------)
Ca (S)     10    34.725       1.225        (-----------*------------)
                                    --+---------+---------+---------+----
Pooled StDev =    1.907            33.0      34.0      35.0      36.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2    0.0137      0.0069      0.45    0.643
Error      22    0.3356      0.0153
Total      24    0.3494
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev ----------+---------+---------+------
Se (H)      5    1.4060      0.0627     (----------------*---------------)
Se (N)     10    1.3535      0.1581   (-----------*-----------)
Se (S)     10    1.3435      0.1027 (-----------*-----------)
                                    ----------+---------+---------+------
Pooled StDev =   0.1235                     1.330     1.400     1.470
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2    2.9069      1.4534     25.00    0.000
Error      22    1.2788      0.0581
Total      24    4.1857
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean       StDev -----+---------+---------+---------+-
Co (H)      5    0.8690      0.5478                        (------*-----)
Co (N)     10    0.0000      0.0000 (----*----)
Co (S)     10    0.0348      0.0935  (----*----)
                                    -----+---------+---------+---------+-
Pooled StDev =   0.2411                0.00      0.35      0.70      1.05

* NOTE  * All values in column are identical.
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       2   0.012655   0.006328       9.15    0.001
Error       22   0.015221   0.000692
Total       24   0.027876
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean      StDev   ---+---------+---------+---------+---
Ga (H)       5   0.16760    0.01511    (-------*-------)
Ga (N)      10   0.22505    0.02419                        (-----*-----)
Ga (S)      10   0.18930    0.03170              (-----*-----)
                                      ---+---------+---------+---------+---
Pooled StDev =   0.02630                0.150     0.180     0.210     0.240
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       2      2.43        1.21       1.21    0.318
Error       22     22.09        1.00
Total       24     24.52
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean      StDev   ----+---------+---------+---------+--
As (H)       5     5.410      1.179          (-------------*-------------)
As (N)      10     5.080      1.271         (----------*---------)
As (S)      10     4.604      0.472   (---------*---------)
                                      ----+---------+---------+---------+--
Pooled StDev =     1.002                 4.20      4.90      5.60      6.30
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       2   0.02214     0.01107       7.82    0.003
Error       22   0.03112     0.00141
Total       24   0.05326
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean      StDev   ----+---------+---------+---------+--
Y (H)        5   0.13072    0.03421                   (---------*--------)
Y (N)       10   0.04927    0.00923   (-----*-----)
Y (S)       10   0.07460    0.05341         (------*-----)
                                      ----+---------+---------+---------+--
Pooled StDev =   0.03761                 0.040     0.080     0.120     0.160
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     1.182     0.591     0.62    0.548
Error      22    21.039     0.956
Total      24    22.221
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Zr (H)      5    0.6993    1.4373      (---------------*--------------)
Zr (N)     10    0.6739    1.1179          (----------*----------)
Zr (S)     10    0.2389    0.4120  (----------*----------)
                                   -------+---------+---------+---------
Pooled StDev =   0.9779                  0.00      0.60      1.20
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.2742    0.1371     7.23    0.004
Error      22    0.4170    0.0190
Total      24    0.6912
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Sn (H)      5    0.3417    0.2774                   (---------*--------)
Sn (N)     10    0.0633    0.0418  (-----*------)
Sn (S)     10    0.1050    0.1020     (-----*------)
                                   --+---------+---------+---------+----
Pooled StDev =   0.1377            0.00      0.15      0.30      0.45
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000835 0.0000418     2.66    0.092
Error      22 0.0003452 0.0000157
Total      24 0.0004287
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
Cs (H)      5  0.007528  0.001899             (-----------*-----------)
Cs (N)     10  0.003273  0.000753  (---------*---------)
Cs (S)     10  0.006656  0.006016              (-------*---------)
                                   --------+---------+---------+--------
Pooled StDev = 0.003961                 0.0030    0.0060    0.0090
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.1751	0.0875	**3.71**	0.041
Error	22	0.5189	0.0236		
Total	24	0.6940			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   --+---------+---------+---------+----
La (H)      5    0.3076    0.2138                (---------*--------)
La (N)     10    0.0785    0.0147    (-----*------)
La (S)     10    0.1504    0.1927        (------*------)
                                    --+---------+---------+---------+----
Pooled StDev =   0.1536             0.00      0.15      0.30      0.45
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.3294	0.1647	3.15	0.063
Error	22	1.1503	0.0523		
Total	24	1.4797			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ------+---------+---------+---------+
Ce (H)      5    0.3519    0.3281                (----------*---------)
Ce (N)     10    0.0379    0.0309   (-------*------)
Ce (S)     10    0.1542    0.2811         (-------*------)
                                    ------+---------+---------+---------+
Pooled StDev =   0.2287                 0.00      0.20      0.40      0.60
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.002997	0.001498	3.14	0.063
Error	22	0.010505	0.000477		
Total	24	0.013501			

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -----+---------+---------+---------+-
Pr (H)      5   0.03452   0.03049              (---------*---------)
Pr (N)     10   0.00465   0.00311   (------*------)
Pr (S)     10   0.01655   0.02728         (------*------)
                                    -----+---------+---------+---------+-
Pooled StDev =  0.02185                0.000     0.020     0.040     0.060
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2   0.04084   0.02042     3.32    0.055
Error      22   0.13541   0.00616
Total      24   0.17625
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Nd (H)      5   0.12904   0.10710              (---------*----------)
Nd (N)     10   0.01870   0.01383  (-------*------)
Nd (S)     10   0.06200   0.09877        (------*------)
                                   -----+---------+---------+---------+-
Pooled StDev =  0.07845               0.000     0.070     0.140     0.210
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2 0.0007887 0.0003944        5.26    0.014
Error      22 0.0016498 0.0000750
Total      24 0.0024385
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Sm (H)      5  0.020052  0.009042                 (---------*---------)
Sm (N)     10  0.004690  0.002503   (------*------)
Sm (S)     10  0.010404  0.011862         (------*------)
                                   --+---------+---------+---------+----
Pooled StDev = 0.008660            0.0000    0.0080    0.0160    0.0240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2 0.0001215 0.0000607        3.46    0.049
Error      22 0.0003860 0.0000175
Total      24 0.0005075
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Eu (H)      5  0.007594  0.008028              (----------*----------)
Eu (N)     10  0.001854  0.002248  (-------*-------)
Eu (S)     10  0.002374  0.003033    (-------*-------)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.004189             0.0000    0.0035    0.0070    0.0105
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      2 0.0000063 0.0000031       1.04    0.369
Error      22 0.0000660 0.0000030
Total      24 0.0000723
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  -+---------+---------+---------+-----
Tb (H)      5  0.001893   0.001003      (---------------*---------------)
Tb (N)     10  0.001100   0.000691   (----------*----------)
Tb (S)     10  0.002198   0.002532             (----------*----------)
                                    -+---------+---------+---------+-----
Pooled StDev = 0.001732            0.0000    0.0010    0.0020    0.0030
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      2  0.001074   0.000537      3.71    0.041
Error      22  0.003181   0.000145
Total      24  0.004255
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  --+---------+---------+---------+----
Gd (H)      5   0.02461    0.01246                (-----------*----------)
Gd (N)     10   0.00670    0.00334   (-------*-------)
Gd (S)     10   0.01353    0.01653          (-------*------)
                                    --+---------+---------+---------+----
Pooled StDev =  0.01202             0.000     0.010     0.020     0.030
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF         SS          MS         F        P
Factor      2 0.0003446  0.0001723      3.78    0.039
Error      22 0.0010024  0.0000456
Total      24 0.0013471
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  ----------+---------+---------+------
Dy (H)      5  0.014796   0.008002               (----------*---------)
Dy (N)     10  0.004633   0.002983  (-------*------)
Dy (S)     10  0.007777   0.008604        (------*------)
                                    ----------+---------+---------+------
Pooled StDev = 0.006750                     0.0060    0.0120    0.0180
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000271 0.0000136     2.44    0.110
Error      22 0.0001222 0.0000056
Total      24 0.0001494
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Ho (H)      5  0.002904  0.001718          (-------------*-------------)
Ho (N)     10  0.000925  0.000620  (---------*---------)
Ho (S)     10  0.003116  0.003448                (---------*---------)
                                   ----+---------+---------+---------+--
Pooled StDev = 0.002357              0.0000    0.0016    0.0032    0.0048
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000480 0.0000240     1.12    0.343
Error      22 0.0004701 0.0000214
Total      24 0.0005181
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
Er (H)      5  0.006454  0.003824         (--------------*-------------)
Er (N)     10  0.003228  0.001276   (---------*---------)
Er (S)     10  0.005795  0.006641          (---------*---------)
                                   ----------+---------+---------+------
Pooled StDev = 0.004622                    0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000016 0.0000008     0.62    0.550
Error      22 0.0000289 0.0000013
Total      24 0.0000305
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Tm (H)      5  0.000584  0.000594  (--------------*---------------)
Tm (N)     10  0.000564  0.000945      (----------*----------)
Tm (S)     10  0.001090  0.001471             (----------*---------)
                                   -------+---------+---------+---------
Pooled StDev = 0.001146                 0.00000   0.00070   0.00140
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000425 0.0000212     0.98    0.392
Error      22 0.0004777 0.0000217
Total      24 0.0005202
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Yb (H)      5  0.005616  0.002658         (--------------*-------------)
Yb (N)     10  0.002196  0.001596  (---------*----------)
Yb(S)      10  0.004102  0.006884        (----------*---------)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.004660             0.0000    0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000044 0.0000022     1.08    0.356
Error      22 0.0000443 0.0000020
Total      24 0.0000487
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Lu (H)      5  0.001206  0.000645    (---------------*----------------)
Lu (N)     10  0.000667  0.000595   (----------*-----------)
Lu (S)     10  0.001599  0.002094             (-----------*-----------)
                                   ----+---------+---------+---------+--
Pooled StDev = 0.001419              0.00000   0.00080   0.00160   0.00240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2  0.000500  0.000250     0.72    0.498
Error      22  0.007643  0.000347
Total      24  0.008143
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Hf (H)      5   0.01459   0.02566     (-------------*--------------)
Hf (N)     10   0.01535   0.02230          (---------*---------)
Hf (S)     10   0.00599   0.00769   (---------*---------)
                                   ------+---------+---------+---------+
Pooled StDev =  0.01864                0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        2 0.0000055 0.0000028        1.11    0.346
Error        22 0.0000544 0.0000025
Total        24 0.0000599
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean      StDev   --------+---------+---------+--------
Ta (H)        5  0.000691   0.000478   (--------------*-------------)
Ta (N)       10  0.001080   0.000959           (----------*---------)
Ta (S)       10  0.001863   0.002242                   (----------*---------)
                                       --------+---------+---------+--------
Pooled StDev = 0.001573                      0.0000    0.0010    0.0020
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        2      83.9       41.9       0.85    0.439
Error        22    1079.8       49.1
Total        24    1163.7
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean      StDev   ------+---------+---------+---------+
W (H)         5     3.690      2.716   (------------*------------)
W (N)        10     8.670      7.832                 (---------*---------)
W (S)        10     6.558      7.441               (--------*--------)
                                       ------+---------+---------+---------+
Pooled StDev =      7.006                   0.0       5.0      10.0      15.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        2 0.0000056 0.0000028        0.32    0.726
Error        22 0.0001881 0.0000085
Total        24 0.0001936
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean      StDev   ------+---------+---------+---------+
Tl (H)        5  0.007988   0.001892    (-----------------*-----------------)
Tl (N)       10  0.007108   0.002701    (-----------*------------)
Tl (S)       10  0.008105   0.003465          (------------*------------)
                                       ------+---------+---------+---------+
Pooled StDev = 0.002924                   0.0060    0.0075    0.0090    0.0105
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2  0.000399  0.000199     1.43    0.260
Error      22  0.003064  0.000139
Total      24  0.003462
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Bi (H)      5   0.02406   0.00971          (----------*----------)
Bi (N)     10   0.01673   0.00641      (-------*------)
Bi (S)     10   0.01312   0.01604  (-------*-------)
                                   -----+---------+---------+---------+-
Pooled StDev =  0.01180               0.010     0.020     0.030     0.040
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0002119 0.0001060     4.71    0.020
Error      22 0.0004950 0.0000225
Total      24 0.0007069
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Th (H)      5  0.009482  0.005525              (--------*--------)
Th (N)     10  0.001771  0.001150  (------*-----)
Th (S)     10  0.005853  0.006333         (------*-----)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.004743             0.0000    0.0050    0.0100    0.0150
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000454 0.0000227     2.34    0.120
Error      22 0.0002139 0.0000097
Total      24 0.0002594
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
U (H)       5  0.005310  0.001654           (----------*-----------)
U (N)      10  0.002157  0.000616  (--------*-------)
U (S)      10  0.004638  0.004709           (--------*-------)
                                   ----------+---------+---------+------
Pooled StDev = 0.003118                    0.0025    0.0050    0.0075
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	1.840	0.920	3.51	0.047
Error	22	5.760	0.262		
Total	24	7.600			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N      Mean     StDev    ----+---------+---------+---------+--
REE Heal     5    0.9088    0.7179                 (---------*---------)
REE Sout    10    0.4351    0.6379          (------*-----)
REE Nort    10    0.1663    0.0632     (-----*------)
                                      ----+---------+---------+---------+--
Pooled StDev =    0.5117                0.00      0.50      1.00      1.50
```

Appendix C: one-way ANOVA of variance results: Control (Excluding Parrsboro), North of the Park, South of the Park

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2      5421      2710     0.50    0.611
Error      21    112712      5367
Total      23    118133
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -+---------+---------+---------+-----
Al (H)      4     72.35     16.77   (--------------*---------------)
Al (N)     10     49.10     45.32    (---------*--------)
Al (S)     10     81.52    101.86          (--------*---------)
                                    -+---------+---------+---------+-----
Pooled StDev =    73.26              0        50       100       150
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS        F        P
Factor      2  0.003050   0.001525     1.87    0.178
Error      21  0.017097   0.000814
Total      23  0.020147
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ---+---------+---------+---------+---
Sb (H)      4   0.02589   0.01718    (--------------*--------------)
Sb (N )    10   0.03933   0.04105              (---------*--------)
Sb (S)     10   0.01465   0.01077    (--------*---------)
                                    ---+---------+---------+---------+---
Pooled StDev =  0.02853              0.000     0.020     0.040     0.060
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     10016      5008     3.64    0.044
Error      21     28882      1375
Total      23     38898
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   --+---------+---------+---------+----
Ba (H)      4    180.50     13.48               (----------*----------)
Ba (N)     10    125.85     25.80    (------*------)
Ba (S)     10    125.52     49.83    (------*------)
                                    --+---------+---------+---------+----
Pooled StDev =    37.09             105       140       175       210
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.2513	0.1256	5.35	0.014
Error	20	0.4697	0.0235		
Total	22	0.7210			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Cd (H)      4    0.3628    0.2391                  (---------*---------)
Cd (N)     10    0.1615    0.1798          (-----*-----)
Cd (S)      9    0.0617    0.0303  (------*------)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.1532               0.00      0.16      0.32      0.48
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.0354	0.0177	1.36	0.279
Error	21	0.2735	0.0130		
Total	23	0.3089			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
Cr (H)      4    0.1797    0.1291          (-----------*-----------)
Cr (N)     10    0.0951    0.1062     (-------*------)
Cr (S)     10    0.0687    0.1164  (-------*------)
                                   -+---------+---------+---------+-----
Pooled StDev =   0.1141           0.00      0.10      0.20      0.30
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	648	324	3.08	0.067
Error	21	2208	105		
Total	23	2855			

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Cu (H)      4     24.27      4.50            (------------*-------------)
Cu(N)      10     22.37     13.13               (-------*-------)
Cu (S)     10     12.46      8.13  (--------*-------)
                                   ---+---------+---------+---------+---
Pooled StDev =    10.25               8.0      16.0      24.0      32.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    110880     55440     1.41    0.267
Error      20    785994     39300
Total      22    896874
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Fe (H)      4     307.8     221.4           (-------------*------------)
Fe (N)      9     107.9      46.5  (--------*--------)
Fe (S)     10     175.9     262.8      (--------*--------)
                                   --+---------+---------+---------+----
Pooled StDev =    198.2                0       150       300       450
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     4.389     2.195     9.21    0.001
Error      21     5.004     0.238
Total      23     9.393
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Pb (H)      4    1.9350    0.9823                 (--------*--------)
Pb (N)     10    0.7231    0.1334   (----*----)
Pb (S)     10    0.8876    0.4653     (-----*----)
                                   ----+---------+---------+---------+--
Pooled StDev =   0.4881               0.60      1.20      1.80      2.40
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     0.156     0.078     0.15    0.863
Error      20    10.577     0.529
Total      22    10.734
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
Li (H)      4    1.2158    0.4118  (--------------*--------------)
Li (N)      9    0.9804    0.6492  (----------*---------)
Li (S)     10    1.0764    0.8626     (---------*--------)
                                   -+---------+---------+---------+-----
Pooled StDev =   0.7272           0.50      1.00      1.50      2.00
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2      1819       909     0.61    0.551
Error      21     31141      1483
Total      23     32960
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ---+---------+---------+---------+---
Mn (H)      4     34.50     22.82    (---------------*---------------)
Mn (N)     10     54.03     33.68                (----------*---------)
Mn (S)     10     59.63     46.39                   (---------*---------)
                                    ---+---------+---------+---------+---
Pooled StDev =    38.51                0        25        50        75
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2   0.00059   0.00030     0.12    0.889
Error      21   0.05226   0.00249
Total      23   0.05285
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -------+---------+---------+---------
Mo (H)      4   0.06112   0.01252   (----------------*-----------------)
Mo (N)     10   0.05029   0.03082      (----------*----------)
Mo (S)     10   0.06000   0.06931         (----------*----------)
                                    -------+---------+---------+---------
Pooled StDev =  0.04989                  0.030     0.060     0.090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS        F        P
Factor      2  0.000124   0.000062     0.16    0.850
Error      21  0.007951   0.000379
Total      23  0.008075
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -+---------+---------+---------+-----
Nb (H)      4   0.02018   0.00357    (----------------*----------------)
Nb (N)     10   0.02258   0.02885           (----------*---------)
Nb (S)     10   0.01761   0.00686       (----------*---------)
                                    -+---------+---------+---------+-----
Pooled StDev =  0.01946            0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.6042    0.3021     8.66    0.002
Error      21    0.7326    0.0349
Total      23    1.3368
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Rb (H)      4    0.8468    0.1069                   (---------*---------)
Rb (N)     10    0.4634    0.1780  (-----*-----)
Rb (S)     10    0.7507    0.2142                 (------*-----)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.1868             0.40      0.60      0.80      1.00
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2   0.01289   0.00645     1.95    0.168
Error      20   0.06607   0.00330
Total      22   0.07897
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Ag (H)      4   0.06255   0.02309      (--------------*--------------)
Ag (N)     10   0.07926   0.08308              (---------*--------)
Ag (S)      9   0.02749   0.01713   (---------*---------)
                                   ----+---------+---------+---------+--
Pooled StDev =  0.05748             0.000     0.040     0.080     0.120
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    208669    104334    32.61    0.000
Error      21     67199      3200
Total      23    275867
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --------+---------+---------+--------
Sr (H)      4    518.50     43.28                          (-----*-----)
Sr (N)     10    269.80     35.95   (---*---)
Sr (S)     10    266.85     74.50   (---*--)
                                   --------+---------+---------+--------
Pooled StDev =    56.57                   300       400       500
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2      1331       666     1.83    0.185
Error      21      7623       363
Total      23      8954
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Ti (H)      4     84.55     12.61   (---------------*----------------)
Ti (N)     10     96.55     25.21                (---------*----------)
Ti (S)     10     80.57     12.59     (---------*----------)
                                   -------+---------+---------+---------
Pooled StDev =    19.05                  72        84        96
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.1471    0.0735     1.74    0.200
Error      21    0.8887    0.0423
Total      23    1.0358
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
V (H)       4    0.5965    0.1967           (------------*-------------)
V (N)      10    0.3918    0.2550   (-------*--------)
V (S)      10    0.3818    0.1443  (--------*-------)
                                   -----+---------+---------+---------+-
Pooled StDev =   0.2057                0.32      0.48      0.64      0.80
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2       323       161     0.76    0.480
Error      21      4454       212
Total      23      4777
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Zn (H)      4     64.55     11.25      (---------------*--------------)
Zn (N)     10     54.92     13.90   (---------*---------)
Zn (S)     10     54.51     16.11   (---------*--------)
                                   ------+---------+---------+---------+
Pooled StDev =    14.56                 50        60        70        80
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.000837	0.000419	3.34	0.055
Error	21	0.002635	0.000125		
Total	23	0.003472			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N      Mean     StDev      ------+---------+---------+---------+
Be (H))      4   0.02858   0.02065                   (----------*----------)
Be (N)      10   0.01155   0.00901      (-------*------)
Be (S)      10   0.01763   0.00833            (-------*-------)
                                        ------+---------+---------+---------+
Pooled StDev =   0.01120                    0.010     0.020     0.030     0.040
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	2377771	1188886	3.00	0.071
Error	21	8309927	395711		
Total	23	10687699			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N      Mean     StDev      -----+---------+---------+---------+-
Mg (H)       4    2767.5     171.9      (----------*----------)
Mg (N)      10    3215.0     633.2                  (------*------)
Mg (S)      10    3643.5     715.9                        (------*------)
                                        -----+---------+---------+---------+-
Pooled StDev =     629.1                   2400      3000      3600      4200
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	4322	2161	0.18	0.838
Error	21	253860	12089		
Total	23	258182			

```
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level        N      Mean     StDev      -----+---------+---------+---------+-
Si (H)       4     152.0      18.6      (---------------*---------------)
Si (N)      10     185.1     136.8                (----------*----------)
Si (S)      10     161.4      96.8             (---------*---------)
                                        -----+---------+---------+---------+-
Pooled StDev =     109.9                     70       140       210       280
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2      0.73      0.37     0.10    0.901
Error      21     73.63      3.51
Total      23     74.37
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Ca (H)      4    35.225     1.436  (---------------*---------------)
Ca (N)     10    34.810     2.448     (---------*---------)
Ca (S)     10    34.725     1.225    (---------*----------)
                                   ---+---------+---------+---------+---
Pooled StDev =    1.873            33.6      34.8      36.0      37.2
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.0200    0.0100     0.64    0.537
Error      21    0.3284    0.0156
Total      23    0.3484
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Se (H)      4    1.4250    0.0532       (---------------*---------------)
Se (N)     10    1.3535    0.1581    (---------*---------)
Se (S)     10    1.3435    0.1027   (---------*---------)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.1251             1.280     1.360     1.440     1.520
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    2.1733    1.0867    18.43    0.000
Error      21    1.2379    0.0589
Total      23    3.4112
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Co (H)      4    0.8238    0.6216                       (-------*------)
Co (N)     10    0.0000    0.0000  (----*----)
Co (S)     10    0.0348    0.0935   (----*----)
                                   -----+---------+---------+---------+-
Pooled StDev =   0.2428                0.00      0.35      0.70      1.05

* NOTE  * All values in column are identical.
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.011248	0.005624	7.78	0.003
Error	21	0.015181	0.000723		
Total	23	0.026429			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N       Mean      StDev   ---+---------+---------+---------+---
Ga (H)       4    0.16900    0.01707   (---------*---------)
Ga (N)      10    0.22505    0.02419                       (-----*-----)
Ga (S)      10    0.18930    0.03170             (-----*-----)
                                       ---+---------+---------+---------+---
Pooled StDev =    0.02689                0.150     0.180     0.210     0.240
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	3.506	1.753	1.79	0.192
Error	21	20.581	0.980		
Total	23	24.088			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N       Mean      StDev   -+---------+---------+---------+-----
As (H)       4     5.6850     1.1612            (------------*------------)
As (N)      10     5.0805     1.2707         (---------*--------)
As (S)      10     4.6035     0.4720   (---------*--------)
                                       -+---------+---------+---------+-----
Pooled StDev =     0.9900             4.00      4.80      5.60      6.40
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.01988	0.00994	6.72	0.006
Error	21	0.03105	0.00148		
Total	23	0.05093			

```
                                         Individual 95% CIs For Mean
                                         Based on Pooled StDev
Level        N       Mean      StDev   ------+---------+---------+---------+
Y (H)        4    0.13265    0.03918                  (--------*--------)
Y (N)       10    0.04927    0.00923    (----*----)
Y (S)       10    0.07460    0.05341         (----*----)
                                       ------+---------+---------+---------+
Pooled StDev =    0.03845                  0.050     0.100     0.150     0.200
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     1.502     0.751     0.77    0.476
Error      21    20.491     0.976
Total      23    21.993
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Zr (H)      4    0.8648    1.6037      (-------------*--------------)
Zr (N)     10    0.6739    1.1179        (---------*--------)
Zr (S)     10    0.2389    0.4120  (---------*---------)
                                   ------+---------+---------+---------+
Pooled StDev =   0.9878                0.00      0.70      1.40      2.10
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.2324    0.1162     5.85    0.010
Error      21    0.4170    0.0199
Total      23    0.6494
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Sn (H)      4    0.3432    0.3203               (---------*---------)
Sn (N)     10    0.0633    0.0418  (-----*-----)
Sn (S)     10    0.1050    0.1020     (-----*-----)
                                   --+---------+---------+---------+----
Pooled StDev =   0.1409            0.00      0.15      0.30      0.45
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000859 0.0000430     2.64    0.095
Error      21 0.0003424 0.0000163
Total      23 0.0004284
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
Cs (H)      4  0.007900  0.001972            (-----------*-----------)
Cs (N)     10  0.003273  0.000753   (------*-------)
Cs (S)     10  0.006656  0.006016            (-------*-------)
                                   ---------+---------+---------+-------
Pooled StDev = 0.004038                  0.0035    0.0070    0.0105
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.1385    0.0692     2.81    0.083
Error      21    0.5171    0.0246
Total      23    0.6556
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
La (H)      4    0.2983    0.2457             (----------*----------)
La (N)     10    0.0785    0.0147  (------*------)
La (S)     10    0.1504    0.1927      (------*------)
                                   --+---------+---------+---------+----
Pooled StDev =   0.1569            0.00      0.15      0.30      0.45
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2    0.2970    0.1485     2.71    0.090
Error      21    1.1495    0.0547
Total      23    1.4464
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Ce (H)      4    0.3584    0.3785            (-----------*-----------)
Ce (N)     10    0.0379    0.0309  (-------*-------)
Ce (S)     10    0.1542    0.2811       (-------*------)
                                   ------+---------+---------+---------+
Pooled StDev =   0.2340                0.00      0.20      0.40      0.60
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2  0.002676  0.001338     2.68    0.092
Error      21  0.010502  0.000500
Total      23  0.013178
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Pr (H)      4   0.03490   0.03519            (----------*-----------)
Pr (N)     10   0.00465   0.00311   (------*-------)
Pr (S)     10   0.01655   0.02728        (------*-------)
                                   ------+---------+---------+---------+
Pooled StDev =  0.02236               0.000     0.020     0.040     0.060
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2   0.03530   0.01765     2.74    0.088
Error      21   0.13541   0.00645
Total      23   0.17071
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Nd (H)      4   0.12855   0.12367              (-----------*-----------)
Nd (N)     10   0.01870   0.01383  (-------*------)
Nd (S)     10   0.06200   0.09877       (-------*------)
                                   -----+---------+---------+---------+-
Pooled StDev =  0.08030               0.000     0.070     0.140     0.210
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0006016 0.0003008     3.88    0.037
Error      21 0.0016283 0.0000775
Total      23 0.0022299
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Sm (H)      4  0.019015  0.010092              (-----------*----------)
Sm (N)     10  0.004690  0.002503   (------*------)
Sm (S)     10  0.010404  0.011862         (------*------)
                                   --+---------+---------+---------+----
Pooled StDev = 0.008806            0.0000    0.0080    0.0160    0.0240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000465 0.0000232     1.52    0.242
Error      21 0.0003211 0.0000153
Total      23 0.0003675
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Eu (H)      4  0.005793  0.008018          (-------------*-------------)
Eu (N)     10  0.001854  0.002248   (-------*---------)
Eu (S)     10  0.002374  0.003033    (--------*--------)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.003910             0.0000    0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      2 0.0000061 0.0000031       0.97    0.394
Error      21 0.0000659 0.0000031
Total      23 0.0000720
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
Tb (H)      4  0.001816  0.001142   (--------------*--------------)
Tb (N)     10  0.001100  0.000691  (----------*----------)
Tb (S)     10  0.002198  0.002532            (---------*---------)
                                   -+---------+---------+---------+-----
Pooled StDev = 0.001772           0.0000    0.0012    0.0024    0.0036
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      2  0.000692  0.000346       2.40    0.115
Error      21  0.003027  0.000144
Total      23  0.003719
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Gd (H)      4   0.02184   0.01249             (------------*------------)
Gd (N)     10   0.00670   0.00334    (-------*--------)
Gd (S)     10   0.01353   0.01653           (-------*-------)
                                   --+---------+---------+---------+----
Pooled StDev =  0.01201            0.000     0.010     0.020     0.030
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      2 0.0002716 0.0001358       2.86    0.080
Error      21 0.0009988 0.0000476
Total      23 0.0012704
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
Dy (H)      4  0.014370  0.009174             (-----------*-----------)
Dy (N)     10  0.004633  0.002983  (-------*-------)
Dy (S)     10  0.007777  0.008604      (-------*-------)
                                   ----------+---------+---------+------
Pooled StDev = 0.006897                   0.0060    0.0120    0.0180
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2 0.0000268 0.0000134      2.31    0.124
Error      21 0.0001222 0.0000058
Total      23 0.0001490
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  ----+---------+---------+---------+--
Ho (H)      4  0.002942   0.001981        (------------*-----------)
Ho (N)     10  0.000925   0.000620   (-------*-------)
Ho (S)     10  0.003116   0.003448             (-------*-------)
                                    ----+---------+---------+---------+--
Pooled StDev = 0.002412               0.0000    0.0020    0.0040    0.0060
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2 0.0000379 0.0000190      0.87    0.435
Error      21 0.0004597 0.0000219
Total      23 0.0004976
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  ----------+---------+---------+------
Er (H)      4  0.005733   0.004004     (---------------*---------------)
Er (N)     10  0.003228   0.001276   (---------*---------)
Er (S)     10  0.005795   0.006641          (---------*----------)
                                    ----------+---------+---------+------
Pooled StDev = 0.004679                     0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS         F        P
Factor      2 0.0000016 0.0000008      0.57    0.575
Error      21 0.0000289 0.0000014
Total      23 0.0000305
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean      StDev  ---------+---------+---------+-------
Tm (H)      4  0.000593   0.000685  (----------------*-----------------)
Tm (N)     10  0.000564   0.000945        (----------*----------)
Tm (S)     10  0.001090   0.001471                (----------*----------)
                                    ---------+---------+---------+-------
Pooled StDev = 0.001173                   0.00000   0.00070   0.00140
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000367 0.0000184     0.81    0.459
Error      21 0.0004775 0.0000227
Total      23 0.0005142
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Yb (H)      4  0.005510  0.003057       (-------------*-------------)
Yb (N)     10  0.002196  0.001596  (---------*--------)
Yb(S)      10  0.004102  0.006884        (---------*--------)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.004768             0.0000    0.0035    0.0070    0.0105
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000044 0.0000022     1.04    0.372
Error      21 0.0000443 0.0000021
Total      23 0.0000487
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Lu (H)      4  0.001233  0.000742  (--------------*--------------)
Lu (N)     10  0.000667  0.000595  (---------*--------)
Lu (S)     10  0.001599  0.002094          (---------*---------)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.001452             0.0000    0.0010    0.0020    0.0030
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.000590	0.000295	0.83	0.451
Error	21	0.007484	0.000356		
Total	23	0.008074			

Level	N	Mean	StDev
Hf (H)	4	0.01741	0.02872
Hf (N)	10	0.01535	0.02230
Hf (S)	10	0.00599	0.00769

Pooled StDev = 0.01888

```
Individual 95% CIs For Mean
Based on Pooled StDev
------+---------+---------+---------+
   (---------------*---------------)
           (----------*---------)
 (---------*----------)
------+---------+---------+---------+
    0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	0.0000049	0.0000025	0.95	0.403
Error	21	0.0000544	0.0000026		
Total	23	0.0000593			

Level	N	Mean	StDev
Ta (H)	4	0.000727	0.000545
Ta (N)	10	0.001080	0.000959
Ta (S)	10	0.001863	0.002242

Pooled StDev = 0.001609

```
Individual 95% CIs For Mean
Based on Pooled StDev
--------+---------+---------+--------
(-------------*-------------)
        (--------*--------)
               (--------*-------)
--------+---------+---------+--------
      0.0000    0.0012    0.0024
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	2	62.0	31.0	0.61	0.555
Error	21	1075.3	51.2		
Total	23	1137.4			

Level	N	Mean	StDev
W (H)	4	4.162	2.889
W (N)	10	8.670	7.832
W (S)	10	6.558	7.441

Pooled StDev = 7.156

```
Individual 95% CIs For Mean
Based on Pooled StDev
-------+---------+---------+---------
(--------------*--------------)
               (--------*---------)
           (--------*---------)
-------+---------+---------+---------
     0.0       5.0      10.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000051 0.0000025     0.28    0.755
Error      21 0.0001873 0.0000089
Total      23 0.0001923
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Tl (H)      4  0.007788  0.002123  (---------------*--------------)
Tl (N)     10  0.007108  0.002701     (----------*---------)
Tl (S)     10  0.008105  0.003465          (---------*---------)
                                   -------+---------+---------+---------
Pooled StDev = 0.002986                 0.0060    0.0080    0.0100
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2  0.000341  0.000171     1.17    0.330
Error      21  0.003063  0.000146
Total      23  0.003405
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Bi (H)      4   0.02403   0.01121        (-------------*------------)
Bi (N)     10   0.01673   0.00641    (--------*--------)
Bi (S)     10   0.01312   0.01604  (--------*--------)
                                   -----+---------+---------+---------+-
Pooled StDev =  0.01208              0.010     0.020     0.030     0.040
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0001867 0.0000933     3.96    0.035
Error      21 0.0004948 0.0000236
Total      23 0.0006814
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Th (H)      4  0.009380  0.006374              (----------*---------)
Th (N)     10  0.001771  0.001150  (------*-----)
Th (S)     10  0.005853  0.006333          (------*-----)
                                   ---+---------+---------+---------+---
Pooled StDev = 0.004854             0.0000    0.0050    0.0100    0.0150
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2 0.0000461 0.0000230     2.27    0.128
Error      21 0.0002129 0.0000101
Total      23 0.0002590
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ----------+---------+---------+------
U (H)       4  0.005537  0.001817            (------------*------------)
U (N)      10  0.002157  0.000616   (---------*--------)
U (S)      10  0.004638  0.004709             (--------*--------)
                                    ----------+---------+---------+------
Pooled StDev = 0.003184                     0.0025    0.0050    0.0075
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      2     1.554     0.777     2.83    0.081
Error      21     5.758     0.274
Total      23     7.312
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ----+---------+---------+---------+--
REE Heal    4    0.8989    0.8285              (-----------*----------)
North      10    0.1663    0.0632   (------*------)
South      10    0.4351    0.6379         (------*------)
                                    ----+---------+---------+---------+--
Pooled StDev =   0.5236               0.00      0.50      1.00      1.50
```

Appendix D: one-way ANOVA of variance results: Control, North of the Park breakage score 1. North of the Park breakage score 2, North of the Park breakage score 3

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F        P
Factor        3       4257       1419      0.91    0.468
Error        11      17165       1560
Total        14      21423
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev ------+---------+---------+---------+
Al (H)        5      73.88      14.92                 (--------*---------)
NTH Al 1      4      60.97      58.04            (----------*----------)
NTH Al 2      3      55.72      55.32         (------------*-----------)
NTH Al 3      3      26.63       5.01 (------------*-----------)
                                      ------+---------+---------+---------+
Pooled StDev =       39.50                  0        40        80       120
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F        P
Factor        3    0.00254    0.00085      0.65    0.598
Error        11    0.01428    0.00130
Total        14    0.01682
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev --------+---------+---------+--------
Sb (H)        5    0.02455    0.01518      (---------*---------)
NTH Sb 1      4    0.05335    0.05916             (----------*-----------)
NTH Sb 2      3    0.02085    0.00755  (------------*------------)
NTH Sb 3      3    0.03913    0.03702      (------------*------------)
                                      --------+---------+---------+--------
Pooled StDev =     0.03603                 0.000     0.035     0.070
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F        P
Factor        3      23190       7730      7.66    0.005
Error        11      11106       1010
Total        14      34296
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev ------+---------+---------+---------+
Ba (H)        5     201.40      48.17                   (-----*------)
NTH Ba 1      4     113.28      21.01   (------*------)
NTH Ba 2      3     157.00       8.89          (-------*-------)
NTH Ba 3      3     111.47      13.09 (-------*-------)
                                      ------+---------+---------+---------+
Pooled StDev =       31.78                100       150       200       250
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3    0.1954    0.0651     1.69    0.227
Error      11    0.4243    0.0386
Total      14    0.6197
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Cd (H)      5    0.3762    0.2092                  (---------*--------)
NTH Cd 1    4    0.0967    0.0564  (----------*----------)
NTH Cd 2    3    0.1567    0.0843   (------------*-----------)
NTH Cd 3    3    0.2525    0.3358       (------------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev =   0.1964                 0.00      0.20      0.40      0.60
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   0.08374   0.02791     3.48    0.054
Error      11   0.08831   0.00803
Total      14   0.17205
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
Cr (H)      5   0.16514   0.11647                (-------*------)
NTH Cr 1    4   0.19425   0.08208                  (-------*-------)
NTH Cr 2    3   0.01137   0.01969  (---------*--------)
NTH Cr 3    3   0.04667   0.08083    (---------*--------)
                                   ---------+---------+---------+-------
Pooled StDev =  0.08960                    0.00      0.12      0.24
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3       511       170     1.62    0.241
Error      11      1155       105
Total      14      1665
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
Cu (H)      5     22.66      5.31            (--------*-------)
NTH Cu 1    4     30.72     16.90                  (---------*--------)
NTH Cu 2    3     19.53      7.95      (----------*----------)
NTH Cu 3    3     14.06      5.40  (----------*----------)
                                   ----------+---------+---------+------
Pooled StDev =    10.25                      12        24        36
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	450511	150170	0.95	0.448
Error	11	1732405	157491		
Total	14	2182915			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev   ---------+---------+---------+-------
Fe (H)       5     318.4     193.2           (-------*-------)
NTH Fe 1     4     139.0      51.0      (---------*---------)
NTH Fe 2     3      96.0      11.8    (----------*----------)
NTH Fe 3     3     575.6     887.4             (-----------*----------)
                                     ---------+---------+---------+-------
Pooled StDev =     396.9                      0       500      1000
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	6.794	2.265	**6.27**	0.010
Error	11	3.972	0.361		
Total	14	10.766			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev   -+---------+---------+---------+-----
Pb (H)       5    2.1500    0.9771                      (-------*------)
NTH Pb 1     4    0.7315    0.2066     (-------*-------)
NTH Pb 2     3    0.6840    0.0877   (----------*--------)
NTH Pb 3     3    0.7510    0.0694    (---------*---------)
                                     -+---------+---------+---------+-----
Pooled StDev =    0.6009            0.00      0.80      1.60      2.40
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	85.6	28.5	1.88	0.191
Error	11	166.4	15.1		
Total	14	252.0			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean     StDev   --------+---------+---------+--------
Li (H)       5     1.066     0.490     (--------*--------)
NTH Li 1     4     0.494     0.124   (---------*---------)
NTH Li 2     3     6.843     9.057               (----------*---------)
NTH Li 3     3     1.206     0.833    (---------*----------)
                                     --------+---------+---------+--------
Pooled StDev =     3.890                    0.0       5.0      10.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3      3293      1098     1.26    0.336
Error      11      9597       872
Total      14     12891
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----------+---------+---------+------
Mn (H)      5     38.40     21.60    (---------*--------)
NTH Mn 1    4     35.20      9.24  (----------*----------)
NTH Mn 2    3     70.97     37.11            (------------*-----------)
NTH Mn 3    3     62.20     48.58         (------------*-----------)
                                   ----------+---------+---------+------
Pooled StDev =    29.54                     30        60        90
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3  0.002459  0.000820     1.15    0.373
Error      11  0.007850  0.000714
Total      14  0.010309
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Mo (H)      5   0.05318   0.02081              (--------*-------)
NTH Mo 1    4   0.05785   0.03313              (---------*---------)
NTH Mo 2    3   0.02677   0.00593   (----------*----------)
NTH Mo 3    3   0.06373   0.03711               (-----------*-----------)
                                   ---+---------+---------+---------+---
Pooled StDev =  0.02671              0.000     0.030     0.060     0.090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3  0.001892  0.000631     1.23    0.346
Error      11  0.005653  0.000514
Total      14  0.007545
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Nb (H)      5   0.02042   0.00314       (--------*--------)
NTH Nb 1    4   0.01343   0.00250   (---------*---------)
NTH Nb 2    3   0.01386   0.00723  (-----------*----------)
NTH Nb 3    3   0.04350   0.05239             (-----------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev =  0.02267                0.000     0.025     0.050     0.075
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3    0.3690    0.1230     3.63    0.049
Error      11    0.3730    0.0339
Total      14    0.7420
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   ---+---------+---------+---------+---
Rb (H)      5    0.7816    0.1726                   (------H-------)
NTH Rb 1    4    0.3948    0.1163    (-------1-------)
NTH Rb 2    3    0.5063    0.2589       (---------2---------)
NTH Rb 3    3    0.5120    0.1989       (---------3---------)
                                    ---+---------+---------+---------+---
Pooled StDev =   0.1841                0.25      0.50      0.75      1.00
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   0.01952   0.00651     1.55    0.256
Error      11   0.04607   0.00419
Total      14   0.06559
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -------+---------+---------+---------
Ag (H)      5   0.05818   0.02225        (---------*--------)
NTH Ag 1    4   0.13090   0.11260                 (---------*---------)
NTH Ag 2    3   0.03828   0.02940   (-----------*-----------)
NTH Ag 3    3   0.05137   0.04649     (-----------*-----------)
                                    -------+---------+---------+---------
Pooled StDev =  0.06472                  0.000     0.070     0.140
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3    136510     45503     8.00    0.004
Error      11     62551      5686
Total      14    199061
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev   -------+---------+---------+---------
Sr (H)      5    468.20    118.55                     (-----H-----)
NTH Sr 1    4    244.00     17.57   (------1------)
NTH Sr 2    3    275.00     20.95     (-------2-------)
NTH Sr 3    3    299.00     47.57       (-------3-------)
                                    -------+---------+---------+---------
Pooled StDev =    75.41                   240       360       480
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3      3881      1294     5.18    0.018
Error       11      2746       250
Total       14      6626
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  -------+---------+---------+---------
Ti (H)       5     87.12     12.34        (-----*-----)
NTH Ti 1     4    119.62     25.48                    (------*------)
NTH Ti 2     3     83.62      8.04    (-------*-------)
NTH Ti 3     3     78.73      5.46  (-------*--------)
                                    -------+---------+---------+---------
Pooled StDev =     15.80                  75       100       125
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3    0.2203    0.0734     1.34    0.311
Error       11    0.6015    0.0547
Total       14    0.8218
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ---+---------+---------+---------+---
V (H)        5    0.5734    0.1780                  (--------*--------)
NTH V  1     4    0.4713    0.1194             (---------*---------)
NTH V  2     3    0.2322    0.0132  (-----------*-----------)
NTH V  3     3    0.4457    0.4646          (-----------*-----------)
                                    ---+---------+---------+---------+---
Pooled StDev =    0.2339              0.00      0.25      0.50      0.75
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3       549       183     1.09    0.393
Error       11      1842       167
Total       14      2391
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev  ----------+---------+---------+------
Zn (H)       5     63.76      9.90                 (--------*-------)
NTH Zn 1     4     59.05     15.54             (--------*---------)
NTH Zn 2     3     57.58     18.93          (----------*----------)
NTH Zn 3     3     46.77      2.12  (----------*----------)
                                    ----------+---------+---------+------
Pooled StDev =     12.94                     45        60        75
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F         P
Factor        3   0.000846   0.000282      1.53     0.261
Error        11   0.002022   0.000184
Total        14   0.002868
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev  -----+---------+---------+---------+-
Be (H)        5    0.02726    0.01812                 (--------*--------)
NTH Be 1      4    0.01334    0.01165      (---------*---------)
NTH Be 2      3    0.00983    0.00973  (-----------*----------)
NTH Be 3      3    0.01088    0.00746   (----------*-----------)
                                       -----+---------+---------+---------+-
Pooled StDev =    0.01356                 0.000     0.015     0.030     0.045
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F         P
Factor        3     785513     261838      0.79     0.523
Error        11    3635247     330477
Total        14    4420760
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev  ----+---------+---------+---------+--
Mg (H)        5     2912.0      355.8     (---------*--------)
NTH Mg 1      4     3435.0      808.6            (---------*----------)
NTH Mg 2      3     3230.0      633.2       (-----------*-----------)
NTH Mg 3      3     2906.7      427.7  (-----------*------------)
                                       ----+---------+---------+---------+--
Pooled StDev =       574.9               2400      3000      3600      4200
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS         MS         F         P
Factor        3      70782      23594      2.52     0.112
Error        11     103064       9369
Total        14     173846
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N       Mean      StDev  -+---------+---------+---------+-----
Si (H)        5     149.40      17.10       (------*-------)
NTH Si 1      4     285.00     183.19                 (--------*--------)
NTH Si 2      3     118.17      17.27   (---------*---------)
NTH Si 3      3     118.83      17.64   (---------*---------)
                                       -+---------+---------+---------+-----
Pooled StDev =       96.80              0        120       240       360
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	6.98	2.33	0.43	0.736
Error	11	59.59	5.42		
Total	14	66.58			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev   -------+---------+---------+---------
Ca (H)        5    34.660     1.773          (---------*--------)
NTH Ca 1      4    34.600     2.174         (---------*----------)
NTH Ca 2      3    33.900     3.407     (-----------*----------)
NTH Ca 3      3    36.000     2.193             (-----------*-----------)
                                      -------+---------+---------+---------
Pooled StDev =      2.328                   32.5      35.0      37.5
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.0432	0.0144	0.77	0.536
Error	11	0.2067	0.0188		
Total	14	0.2499			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev   -------+---------+---------+---------
Se (H)        5    1.4060    0.0627                (--------*--------)
NTH Se 1      4    1.4125    0.2229               (---------*---------)
NTH Se 2      3    1.2717    0.1360   (-----------*----------)
NTH Se 3      3    1.3567    0.0493         (-----------*-----------)
                                      -------+---------+---------+---------
Pooled StDev =     0.1371                    1.20      1.35      1.50
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	2.517	0.839	**7.69**	0.005
Error	11	1.200	0.109		
Total	14	3.717			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev   ---------+---------+---------+-------
Co (H)        5    0.8690    0.5478                      (-----*------)
NTH Co 1      4    0.0000    0.0000     (------*------)
NTH Co 2      3    0.0000    0.0000    (-------*-------)
NTH Co 3      3    0.0000    0.0000    (-------*-------)
                                      ---------+---------+---------+-------
Pooled StDev =     0.3303                     0.00      0.50      1.00
```

* NOTE * All values in column are identical.

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.012680	0.004227	**10.33**	0.002
Error	11	0.004500	0.000409		
Total	14	0.017180			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev  -+---------+---------+---------+-----
Ga (H)        5   0.16760   0.01511  (------*------)
NTH Ga 1      4   0.23550   0.02133                      (-------*------)
NTH Ga 2      3   0.20550   0.03196            (--------*--------)
NTH Ga 3      3   0.23067   0.00945                   (--------*-------)
                                     -+---------+---------+---------+-----
Pooled StDev =    0.02023           0.150     0.180     0.210     0.240
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	1.87	0.62	0.37	0.777
Error	11	18.58	1.69		
Total	14	20.45			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev  ------+---------+---------+---------+
As (H)        5     5.410     1.179            (----------*----------)
NTH As 1      4     5.505     1.791            (-----------*-----------)
NTH As 2      3     4.572     0.543  (-------------*-------------)
NTH As 3      3     5.023     1.185     (-------------*-------------)
                                     ------+---------+---------+---------+
Pooled StDev =      1.300                 3.6       4.8       6.0       7.2
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.022323	0.007441	**15.62**	0.000
Error	11	0.005240	0.000476		
Total	14	0.027563			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level         N      Mean     StDev  ------+---------+---------+---------+
Y (H)         5   0.13072   0.03421                       (-----H----)
NTH Y  1      4   0.04560   0.00351   (-----1-----)
NTH Y  2      3   0.04728   0.00738   (------2------)
NTH Y  3      3   0.05613   0.01438     (------3------)
                                     ------+---------+---------+---------+
Pooled StDev =    0.02182                0.040     0.080     0.120     0.160
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       4      1.53       0.38       0.28    0.887
Error       14     19.22       1.37
Total       18     20.75
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level        N      Mean      StDev   --+---------+---------+---------+----
Zr (H)       5     0.699      1.437           (----------*----------)
Zr (H1)      4     0.057      0.029   (------------*-----------)
NTH Zr 1     4     0.876      1.649           (------------*-----------)
NTH Zr 2     3     0.487      0.714     (--------------*-------------)
NTH Zr 3     3     0.591      0.943      (--------------*-------------)
                                      --+---------+---------+---------+----
Pooled StDev =     1.172             -1.0       0.0       1.0       2.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       4    0.4830     0.1208       3.35    0.040
Error       14    0.5042     0.0360
Total       18    0.9872
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level        N      Mean      StDev   --------+---------+---------+--------
Sn (H)       5    0.3417     0.2774                  (-------*------)
Sn (H1)      4    0.4200     0.2485                     (-------*-------)
NTH Sn 1     4    0.0518     0.0310     (-------*-------)
NTH Sn 2     3    0.0461     0.0055   (---------*--------)
NTH Sn 3     3    0.0957     0.0642     (---------*--------)
                                      --------+---------+---------+--------
Pooled StDev =    0.1898                    0.00      0.25      0.50
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0000605  0.0000202      11.43    0.001
Error       11 0.0000194  0.0000018
Total       14 0.0000799
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level        N      Mean      StDev   ---+---------+---------+---------+---
Cs (H)       5  0.007528   0.001899                         (------*-----)
NTH Cs 1     4  0.003412   0.001117      (------*------)
NTH Cs 2     3  0.003163   0.000708   (---------*--------)
NTH Cs 3     3  0.003197   0.000336    (--------*-------)
                                      ---+---------+---------+---------+---
Pooled StDev = 0.001328                 0.0020    0.0040    0.0060    0.0080
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS         F        P
Factor        3    0.1756     0.0585      3.50    0.053
Error        11    0.1842     0.0167
Total        14    0.3597
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  -------+---------+---------+---------
La (H)        5    0.3076     0.2138                     (---------*--------)
NTH La 1      4    0.0853     0.0198    (---------*---------)
NTH La 2      3    0.0812     0.0081  (----------*----------)
NTH La 3      3    0.0668     0.0034 (----------*----------)
                                      -------+---------+---------+---------
Pooled StDev =     0.1294                  0.00      0.15      0.30
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS         F        P
Factor        3    0.3302     0.1101      2.77    0.092
Error        11    0.4377     0.0398
Total        14    0.7679
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  ----------+---------+---------+------
Ce (H)        5    0.3519     0.3281                  (-------*-------)
NTH Ce 1      4    0.0531     0.0457    (--------*--------)
NTH Ce 2      3    0.0242     0.0057  (---------*---------)
NTH Ce 3      3    0.0315     0.0182  (---------*---------)
                                      ----------+---------+---------+------
Pooled StDev =     0.1995                     0.00      0.25      0.50
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS         F        P
Factor        3  0.002988   0.000996      2.89    0.084
Error        11  0.003792   0.000345
Total        14  0.006780
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  -+---------+---------+---------+-----
Pr (H)        5   0.03452    0.03049                     (---------*--------)
NTH Pr 1      4   0.00593    0.00420     (---------*---------)
NTH Pr 2      3   0.00314    0.00085  (-----------*----------)
NTH Pr 3      3   0.00445    0.00308  (-----------*-----------)
                                      -+---------+---------+---------+-----
Pooled StDev =    0.01857           -0.020     0.000     0.020     0.040
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   0.04075   0.01358     3.15    0.069
Error      11   0.04743   0.00431
Total      14   0.08819
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
Nd (H)      5   0.12904   0.10710                  (-------*-------)
NTH Nd 1    4   0.02348   0.02003    (--------*--------)
NTH Nd 2    3   0.01365   0.00791  (----------*---------)
NTH Nd 3    3   0.01738   0.01050   (---------*----------)
                                   ---------+---------+---------+-------
Pooled StDev =  0.06567                 0.000     0.080     0.160
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      3 0.0007870 0.0002623      7.53    0.005
Error      11 0.0003831 0.0000348
Total      14 0.0011701
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Sm (H)      5  0.020052  0.009042                    (------*------)
NTH Sm 1    4  0.004627  0.001695   (-------*-------)
NTH Sm 2    3  0.004497  0.002234  (---------*--------)
NTH Sm 3    3  0.004967  0.004327   (--------*---------)
                                   ----+---------+---------+---------+--
Pooled StDev = 0.005901              0.0000    0.0080    0.0160    0.0240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      3 0.0001137 0.0000379      1.39    0.297
Error      11 0.0002994 0.0000272
Total      14 0.0004131
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Eu (H)      5  0.007594  0.008028                 (---------*---------)
NTH Eu 1    4  0.002573  0.003075      (----------*----------)
NTH Eu 2    3  0.001640  0.001709   (------------*------------)
NTH Eu 3    3  0.001110  0.001923   (------------*-----------)
                                   --+---------+---------+---------+----
Pooled StDev = 0.005217          -0.0050    0.0000    0.0050    0.0100
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0000042 0.0000014        2.49    0.115
Error       11 0.0000062 0.0000006
Total       14 0.0000104
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ----+---------+---------+---------+--
Tb (H)       5  1.89E-03  1.00E-03                  (----------*---------)
NTH Tb 1     4  1.66E-03  7.78E-04              (----------*---------)
NTH Tb 2     3  7.55E-04  3.50E-04   (----------*-----------)
NTH Tb 3     3  6.95E-04  2.48E-04  (-----------*-----------)
                                    ----+---------+---------+---------+--
Pooled StDev = 7.51E-04               0.00000   0.00080   0.00160   0.00240
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0010988 0.0003663        5.81    0.012
Error       11 0.0006930 0.0000630
Total       14 0.0017918
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  -----+---------+---------+---------+-
Gd (H)       5  0.024612  0.012465                   (------*-----)
NTH Gd 1     4  0.008602  0.004110     (------*------)
NTH Gd 2     3  0.006347  0.002696  (-------*--------)
NTH Gd 3     3  0.004513  0.001771 (---------*-------)
                                    -----+---------+---------+---------+-
Pooled StDev = 0.007937                0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0003511 0.0001170        3.91    0.040
Error       11 0.0003295 0.0000300
Total       14 0.0006805
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ------+---------+---------+---------+
Dy (H)       5  0.014796  0.008002                   (-------*-------)
NTH Dy 1     4  0.005145  0.002915      (-------*--------)
NTH Dy 2     3  0.003377  0.001520  (---------*---------)
NTH Dy 3     3  0.005207  0.004648     (--------*---------)
                                    ------+---------+---------+---------+
Pooled StDev = 0.005473               0.0000    0.0070    0.0140    0.0210
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      3 0.0000147 0.0000049       3.94    0.039
Error      11 0.0000136 0.0000012
Total      14 0.0000283
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level         N      Mean     StDev  ------+---------+---------+---------+
Ho (H)        5  0.002904  0.001718                  (------*-------)
NTH Ho 1      4  0.001413  0.000524            (-------*--------)
NTH Ho 2      3  0.000675  0.000403      (---------*--------)
NTH Ho 3      3  0.000526  0.000588     (---------*--------)
                                     ------+---------+---------+---------+
Pooled StDev = 0.001114                  0.0000    0.0015    0.0030    0.0045
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      3 0.0000392 0.0000131       2.09    0.160
Error      11 0.0000687 0.0000062
Total      14 0.0001078
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level         N      Mean     StDev  ---+---------+---------+---------+---
Er (H)        5  0.006454  0.003824                (--------*-------)
NTH Er 1      4  0.003987  0.001679         (--------*--------)
NTH Er 2      3  0.002397  0.000396  (----------*----------)
NTH Er 3      3  0.003047  0.000838     (---------*----------)
                                     ---+---------+---------+---------+---
Pooled StDev = 0.002499                0.0000    0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS          MS          F        P
Factor      3 0.0000008 0.0000003       0.35    0.790
Error      11 0.0000086 0.0000008
Total      14 0.0000094
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level         N      Mean     StDev  -+---------+---------+---------+-----
Tm (H)        5  5.84E-04  5.94E-04         (----------*----------)
NTH Tm 1      4  9.10E-04  1.50E-03            (-----------*------------)
NTH Tm 2      3  2.69E-04  2.85E-04  (-------------*-------------)
NTH Tm 3      3  3.97E-04  3.88E-04    (-------------*-------------)
                                     -+---------+---------+---------+-----
Pooled StDev = 8.85E-04            -0.00080   0.00000   0.00080   0.00160
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      3 0.0000028 0.0000009      1.46    0.278
Error      11 0.0000069 0.0000006
Total      14 0.0000097
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Ta (H)      5  6.91E-04  4.78E-04      (---------*--------)
NTH Ta 1    4  1.66E-03  1.17E-03                 (----------*----------)
NTH Ta 2    3  6.58E-04  2.59E-04   (------------*------------)
NTH Ta 3    3  7.26E-04  9.42E-04   (-------------*------------)
                                   -----+---------+---------+---------+-
Pooled StDev = 7.94E-04              0.00000   0.00080   0.00160   0.00240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      3     133.8       44.6      0.92    0.461
Error      11     530.4       48.2
Total      14     664.2
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
W (H)       5     3.690     2.716   (----------*-----------)
NTH W  1    4    11.150     9.068             (------------*-----------)
NTH W  2    3     5.720     6.312   (--------------*-------------)
NTH W  3    3     8.313     9.342       (---------------*--------------)
                                   ------+---------+---------+---------+
Pooled StDev =    6.944                  0.0       6.0      12.0      18.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        P
Factor      3 0.0000364 0.0000121      2.89    0.084
Error      11 0.0000462 0.0000042
Total      14 0.0000826
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Tl (H)      5  0.007988  0.001892            (-------*-------)
NTH Tl 1    4  0.005747  0.001033   (--------*--------)
NTH Tl 2    3  0.009907  0.003676                (----------*---------)
NTH Tl 3    3  0.006123  0.000902   (---------*----------)
                                   -------+---------+---------+---------
Pooled StDev = 0.002049                0.0050    0.0075    0.0100
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3 0.0000447 0.0000149     3.61    0.049
Error      11 0.0000455 0.0000041
Total      14 0.0000902
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Yb (H)      5  0.005616  0.002658                     (-------*-------)
NTH Yb 1    4  0.003058  0.001701             (---------*---------)
NTH Yb 2    3  0.001258  0.000697   (---------*----------)
NTH Yb 3    3  0.001987  0.001942     (---------*----------)
                                   ------+---------+---------+---------+
Pooled StDev = 0.002033                0.0000    0.0025    0.0050    0.0075
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3 0.0000015 0.0000005     1.26    0.337
Error      11 0.0000043 0.0000004
Total      14 0.0000058
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Lu (H)      5  1.21E-03  6.45E-04                (--------*--------)
NTH Lu 1    4  8.90E-04  8.87E-04           (---------*---------)
NTH Lu 2    3  3.43E-04  3.02E-04   (----------*----------)
NTH Lu 3    3  6.95E-04  2.48E-04       (----------*----------)
                                   -------+---------+---------+---------
Pooled StDev = 6.27E-04                0.00000   0.00070   0.00140
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3  0.000211  0.000070     0.11    0.951
Error      11  0.006901  0.000627
Total      14  0.007112
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
Hf (H)      5   0.01459   0.02566       (-----------*------------)
NTH Hf 1    4   0.02074   0.03437         (------------*-------------)
NTH Hf 2    3   0.01337   0.01241   (---------------*---------------)
NTH Hf 3    3   0.01014   0.01443  (---------------*---------------)
                                   -+---------+---------+---------+-----
Pooled StDev =  0.02505          -0.020     0.000     0.020     0.040
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        3 0.0001820 0.0000607       0.90    0.474
Error        11 0.0007444 0.0000677
Total        14 0.0009264
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  -+---------+---------+---------+-----
Bi (H)        5  0.024060  0.009711                (-----------*-----------)
NTH Bi 1      4  0.016075  0.002473   (------------*------------)
NTH Bi 2      3  0.017117  0.006764   (--------------*--------------)
NTH Bi 3      3  0.017213  0.011343   (--------------*--------------)
                                     -+---------+---------+---------+-----
Pooled StDev = 0.008226             0.0070    0.0140    0.0210    0.0280
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        3 0.0002004 0.0000668       5.58    0.014
Error        11 0.0001318 0.0000120
Total        14 0.0003322
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  -------+---------+---------+---------
Th (H)        5  0.009482  0.005525                    (------H------)
NTH Th 1      4  0.002329  0.001515     (-------1------)
NTH Th 2      3  0.001556  0.001112   (---------2--------)
NTH Th 3      3  0.001241  0.000395   (--------3--------)
                                     -------+---------+---------+---------
Pooled StDev = 0.003461                  0.0000    0.0050    0.0100
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        3 0.0000344 0.0000115       9.66    0.002
Error        11 0.0000131 0.0000012
Total        14 0.0000475
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  ---------+---------+---------+-------
U (H)         5  0.005310  0.001654                   (-----H----)
NTH U  1      4  0.002550  0.000409       (-----1-----)
NTH U  2      3  0.002100  0.000244     (------2-----)
NTH U  3      3  0.001688  0.000867   (-----3------)
                                     ---------+---------+---------+-------
Pooled StDev = 0.001090                   0.0020    0.0040    0.0060
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	1.845	0.615	3.24	0.064
Error	11	2.089	0.190		
Total	14	3.935			

```
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level          N      Mean     StDev  ---------+---------+---------+-------
REE Health     5    0.9088    0.7179                     (--------*--------)
REE N  1       4    0.2006    0.0884    (---------*---------)
REE N  2       3    0.1437    0.0235  (----------*----------)
REE N  3       3    0.1433    0.0419  (----------*----------)
                                      ---------+---------+---------+-------
Pooled StDev =   0.4358                     0.00      0.50      1.00
```

Appendix E: one-way ANOVA of variance results: Control, South of the Park breakage score 1. South of the Park breakage score 2, South of the Park breakage score 3

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	4257	1419	0.91	0.468
Error	11	17165	1560		
Total	14	21423			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Al (H)      5     73.88     14.92                  (---------*---------)
STH Al 1    4     60.97     58.04             (----------*----------)
STH Al 2    3     55.72     55.32          (------------*-----------)
STH Al 3    3     26.63      5.01  (------------*-----------)
                                   ------+---------+---------+---------+
Pooled StDev =    39.50                  0        40        80       120
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.000574	0.000191	1.22	0.347
Error	11	0.001719	0.000156		
Total	14	0.002293			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Sb (H)      5   0.02455   0.01518                (----------*----------)
STH Sb 1    4   0.00986   0.00472   (----------*-----------)
STH Sb 2    3   0.02180   0.01801          (------------*------------)
STH Sb 3    3   0.01390   0.00641    (-------------*------------)
                                   ----+---------+---------+---------+--
Pooled StDev =  0.01250              0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	26608	8869	**4.03**	0.037
Error	11	24213	2201		
Total	14	50821			

```
                                          Individual 95% CIs For Mean
                                          Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Ba (H)      5    201.40     48.17                    (-------*------)
STH Ba 1    4    112.02     46.96    (--------*--------)
STH Ba 2    3    102.37     17.73  (---------*---------)
STH Ba 3    3    166.67     62.00            (---------*---------)
                                   ---+---------+---------+---------+---
Pooled StDev =    46.92               60       120       180       240
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3     11.18        3.73       1.30    0.323
Error        11     31.54        2.87
Total        14     42.72
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level         N      Mean       StDev   -+---------+---------+---------+-----
Cd (H)        5     0.376       0.209         (-------*-------)
STH Cd 1      4     0.063       0.026      (--------*---------)
STH Cd 2      3     2.328       3.960             (----------*---------)
STH Cd 3      3     0.073       0.045     (---------*----------)
                                        -+---------+---------+---------+-----
Pooled StDev =      1.693             -2.0       0.0       2.0       4.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3    0.0590      0.0197       1.46    0.279
Error        11    0.1483      0.0135
Total        14    0.2073
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level         N      Mean       StDev   ---+---------+---------+---------+---
Cr (H)        5    0.1651      0.1165                   (---------*--------)
STH Cr 1      4    0.1270      0.1571               (----------*---------)
STH Cr 2      3    0.0596      0.1000         (-----------*-----------)
STH Cr 3      3    0.0000      0.0000     (-----------*-----------)
                                        ---+---------+---------+---------+---
Pooled StDev =     0.1161               -0.12      0.00      0.12      0.24

* NOTE  * All values in column are identical.
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3     515.0       171.7       3.50    0.053
Error        11     539.3        49.0
Total        14    1054.3
                                        Individual 95% CIs For Mean
                                        Based on Pooled StDev
Level         N      Mean       StDev   --+---------+---------+---------+----
Cu (H)        5    22.660       5.312                      (------*------)
STH Cu 1      4    17.282      10.847                 (------*-------)
STH Cu 2      3    10.743       5.725          (--------*--------)
STH Cu 3      3     7.753       1.991     (--------*--------)
                                        --+---------+---------+---------+----
Pooled StDev =      7.002                 0        10        20        30
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3    179146     59715     1.00    0.431
Error      11    659528     59957
Total      14    838674
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level       N      Mean     StDev    ---------+---------+---------+-------
Fe (H)      5     318.4     193.2                (---------*--------)
STH Fe 1    4     106.8      38.6      (----------*----------)
STH Fe 2    3     337.1     499.6              (------------*------------)
STH Fe 3    3     106.8      57.5     (-----------*------------)
                                     ---------+---------+---------+-------
Pooled StDev =    244.9                       0        250       500
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     5.321     1.774     3.39    0.058
Error      11     5.760     0.524
Total      14    11.081
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level       N      Mean     StDev    -+---------+---------+---------+-----
Pb (H)      5    2.1500    0.9771                    (--------*--------)
STH Pb 1    4    0.9055    0.3943      (---------*---------)
STH Pb 2    3    0.9075    0.8471     (-----------*-----------)
STH Pb 3    3    0.8437    0.1391    (-----------*----------)
                                     -+---------+---------+---------+-----
Pooled StDev =   0.7236             0.00      0.80      1.60      2.40
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     1.411     0.470     0.83    0.506
Error      11     6.245     0.568
Total      14     7.656
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level       N      Mean     StDev    --+---------+---------+---------+----
Li (H)      5    1.0658    0.4895          (--------*---------)
STH Li 1    4    0.8503    0.4971      (----------*---------)
STH Li 2    3    0.8050    0.7482    (-----------*-----------)
STH Li 3    3    1.6493    1.3088               (-----------*-----------)
                                     --+---------+---------+---------+----
Pooled StDev =   0.7535              0.00      0.80      1.60      2.40
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     13679      4560     5.54    0.015
Error      11      9059       824
Total      14     22737
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Mn (H)      5     38.40     21.60      (-----*----)
STH Mn 1    4     41.75     12.42      (-----*------)
STH Mn 2    3     30.63     18.98   (------*------)
STH Mn 3    3    112.47     54.81                    (------*-------)
                                   --+---------+---------+---------+----
Pooled StDev =    28.70              0        50       100       150
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   0.00395   0.00132     0.35    0.789
Error      11   0.04118   0.00374
Total      14   0.04513
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -------+---------+---------+---------
Mo (H)      5   0.05318   0.02081        (---------*---------)
STH Mo 1    4   0.08273   0.10692            (----------*----------)
STH Mo 2    3   0.03720   0.01580  (------------*------------)
STH Mo 3    3   0.05250   0.04823     (------------*------------)
                                   -------+---------+---------+---------
Pooled StDev =  0.06118                 0.000     0.060     0.120
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3 0.0000752 0.0000251     0.67    0.590
Error      11 0.0004137 0.0000376
Total      14 0.0004889
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Nb (H)      5  0.020420  0.003140            (---------*---------)
STH Nb 1    4  0.015475  0.003800   (----------*----------)
STH Nb 2    3  0.020783  0.012228         (------------*------------)
STH Nb 3    3  0.017267  0.003993    (------------*------------)
                                   ------+---------+---------+---------+
Pooled StDev = 0.006133              0.0120    0.0180    0.0240    0.0300
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.0984	0.0328	0.83	0.507
Error	11	0.4370	0.0397		
Total	14	0.5354			

Level	N	Mean	StDev
Rb (H)	5	0.7816	0.1726
STH Rb 1	4	0.6450	0.0963
STH Rb 2	3	0.8800	0.3388
STH Rb 3	3	0.7623	0.1738

Pooled StDev = 0.1993

```
Individual 95% CIs For Mean
Based on Pooled StDev
---------+---------+---------+-------
        (---------*---------)
(----------*----------)
          (------------*------------)
    (------------*------------)
---------+---------+---------+-------
       0.60      0.80      1.00
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	0.0836	0.0279	0.91	0.466
Error	11	0.3359	0.0305		
Total	14	0.4195			

Level	N	Mean	StDev
Ag (H)	5	0.0582	0.0223
STH Ag 1	4	0.2038	0.3332
STH Ag 2	3	0.0288	0.0206
STH Ag 3	3	0.0163	0.0067

Pooled StDev = 0.1748

```
Individual 95% CIs For Mean
Based on Pooled StDev
-+---------+---------+---------+-----
     (--------*--------)
            (--------*---------)
 (----------*----------)
 (----------*----------)
-+---------+---------+---------+-----
-0.20      0.00      0.20      0.40
```

One-way Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Factor	3	145619	48540	5.58	0.014
Error	11	95690	8699		
Total	14	241308			

Level	N	Mean	StDev
Sr (H)	5	468.20	118.55
STH Sr 1	4	236.00	82.72
STH Sr 2	3	261.17	32.23
STH Sr 3	3	313.67	91.82

Pooled StDev = 93.27

```
Individual 95% CIs For Mean
Based on Pooled StDev
---------+---------+---------+-------
                    (-------*-------)
(-------*-------)
 (---------*---------)
     (---------*---------)
---------+---------+---------+-------
       240       360       480
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF          SS          MS         F        P
Factor        3         520         173      1.15    0.372
Error        11        1658         151
Total        14        2178
                                           Individual 95% CIs For Mean
                                           Based on Pooled StDev
Level         N        Mean       StDev   --+---------+---------+---------+----
Ti (H)        5       87.12       12.34               (-------*-------)
STH Ti 1      4       79.42        3.22         (--------*--------)
STH Ti 2      3       89.17       21.75              (---------*----------)
STH Ti 3      3       73.50        5.98     (---------*---------)
                                          --+---------+---------+---------+----
Pooled StDev =        12.28                 60        75        90       105
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF          SS          MS         F        P
Factor        3      0.1511      0.0504      1.94    0.182
Error        11      0.2855      0.0260
Total        14      0.4366
                                           Individual 95% CIs For Mean
                                           Based on Pooled StDev
Level         N        Mean       StDev   -+---------+---------+---------+-----
V (H)         5      0.5734      0.1780                  (---------*---------)
STH V  1      4      0.3217      0.0832   (----------*----------)
STH V  2      3      0.4495      0.2461         (------------*------------)
STH V  3      3      0.3940      0.0920      (------------*-----------)
                                          -+---------+---------+---------+-----
Pooled StDev =       0.1611              0.16      0.32      0.48      0.64
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF          SS          MS         F        P
Factor        3        1298         433      2.77    0.091
Error        11        1715         156
Total        14        3012
                                           Individual 95% CIs For Mean
                                           Based on Pooled StDev
Level         N        Mean       StDev   ---+---------+---------+---------+---
Zn (H)        5       63.76        9.90                 (-------*-------)
STH Zn 1      4       51.30       12.26         (--------*--------)
STH Zn 2      3       44.12        9.54     (---------*--------)
STH Zn 3      3       69.20       18.57                  (---------*---------)
                                          ---+---------+---------+---------+---
Pooled StDev =        12.49                  32        48        64        80
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       3    0.000394    0.000131     0.78    0.530
Error       11    0.001853    0.000168
Total       14    0.002247
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean       StDev   -+---------+---------+---------+-----
Be (H)       5    0.02726    0.01812               (----------*---------)
STH Be 1     4    0.01422    0.00053    (-----------*-----------)
STH Be 2     3    0.02100    0.01187        (------------*-------------)
STH Be 3     3    0.01880    0.01134      (-------------*------------)
                                       -+---------+---------+---------+-----
Pooled StDev =    0.01298             0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       3     4707285     1569095     7.86    0.004
Error       11     2195438      199585
Total       14     6902723
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean       StDev   -----+---------+---------+---------+-
Mg (H)       5     2912.0      355.8   (------*-----)
STH Mg 1     4     2982.5      310.6    (------*------)
STH Mg 2     3     4041.7      782.9                  (-------*-------)
STH Mg 3     3     4126.7      294.8                   (-------*-------)
                                       -----+---------+---------+---------+-
Pooled StDev =      446.7                2800      3500      4200      4900
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS          MS          F        P
Factor       3        8005        2668     0.38    0.772
Error       11       78037        7094
Total       14       86042
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
Level        N      Mean       StDev   -----+---------+---------+---------+-
Si (H)       5     149.40      17.10       (-----------*-----------)
STH Si 1     4     127.80      55.42   (------------*------------)
STH Si 2     3     185.77     158.69         (---------------*--------------)
STH Si 3     3     181.67      92.98         (--------------*---------------)
                                       -----+---------+---------+---------+-
Pooled StDev =      84.23                  70       140       210       280
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3      5.75      1.92     1.04    0.415
Error       11     20.35      1.85
Total       14     26.10
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  --------+---------+---------+--------
Ca (H)       5    34.660     1.773            (---------*---------)
STH Ca 1     4    35.425     1.266                (----------*----------)
STH Ca 2     3    33.617     0.718   (-----------*-----------)
STH Ca 3     3    34.900     0.985           (-----------*----------)
                                    --------+---------+---------+--------
Pooled StDev =     1.360                  33.0      34.5      36.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3   0.02861   0.00954     1.10    0.389
Error       11   0.09504   0.00864
Total       14   0.12364
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ----------+---------+---------+------
Se (H)       5    1.4060    0.0627             (---------*--------)
STH Se 1     4    1.3050    0.0835  (----------*----------)
STH Se 2     3    1.3383    0.1578    (-----------*-----------)
STH Se 3     3    1.4000    0.0656          (-----------*-----------)
                                    ----------+---------+---------+------
Pooled StDev =    0.0929                    1.30      1.40      1.50
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3     2.337     0.779     6.80    0.007
Error       11     1.261     0.115
Total       14     3.598
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level        N      Mean     StDev  ---------+---------+---------+-------
Co (H)       5    0.8690    0.5478                    (-----*------)
STH Co 1     4    0.0128    0.0257    (------*--------)
STH Co 2     3    0.0990    0.1715    (---------*--------)
STH Co 3     3    0.0000    0.0000  (--------*--------)
                                    ---------+---------+---------+-------
Pooled StDev =    0.3386                   0.00      0.50      1.00

* NOTE  * All values in column are identical.
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3  0.006562  0.002187     4.85    0.022
Error      11  0.004963  0.000451
Total      14  0.011525
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev  ---+---------+---------+---------+---
Ga (H)      5   0.16760   0.01511    (------H------)
STH Ga 1    4   0.21650   0.01700                  (-------1-------)
STH Ga 2    3   0.17433   0.02706    (--------2--------)
STH Ga 3    3   0.16800   0.02931  (--------3--------)
                                   ---+---------+---------+---------+---
Pooled StDev =  0.02124             0.150     0.180     0.210     0.240
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     2.368     0.789     1.18    0.362
Error      11     7.363     0.669
Total      14     9.731
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
As (H)      5    5.4100    1.1787              (---------*---------)
STH As 1    4    4.4725    0.3412   (----------*----------)
STH As 2    3    4.5717    0.5821  (------------*------------)
STH As 3    3    4.8100    0.6239     (------------*------------)
                                   ------+---------+---------+---------+
Pooled StDev =   0.8181                4.00      4.80      5.60      6.40
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3   0.01552   0.00517     2.25    0.140
Error      11   0.02533   0.00230
Total      14   0.04085
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Level       N      Mean     StDev  --+---------+---------+---------+----
Y (H)       5   0.13072   0.03421                     (---------*---------)
STH Y  1    4   0.04715   0.01498   (---------*----------)
STH Y  2    3   0.09360   0.08350          (-----------*-----------)
STH Y  3    3   0.09220   0.05492         (-----------*------------)
                                   --+---------+---------+---------+----
Pooled StDev =  0.04799            0.000     0.050     0.100     0.150
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      4     1.262     0.315     0.46    0.764
Error      14     9.594     0.685
Total      18    10.856
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -----+---------+---------+---------+-
Zr (H)      5    0.6993    1.4373               (----------*----------)
Zr (H1)     4    0.0567    0.0285     (------------*-----------)
STH Zr 1    4    0.3597    0.6137         (------------*------------)
STH Zr 2    3    0.2886    0.3152      (---------------*---------------)
STH Zr 3    3    0.0279    0.0014   (-------------*--------------)
                                   -----+---------+---------+---------+-
Pooled StDev =   0.8278              -0.70      0.00      0.70      1.40
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      4    0.3899    0.0975     2.44    0.096
Error      14    0.5594    0.0400
Total      18    0.9493
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
Sn (H)      5    0.3417    0.2774                (--------*-------)
Sn (H1)     4    0.4200    0.2485                  (---------*--------)
STH Sn 1    4    0.1356    0.0749       (--------*---------)
STH Sn 2    3    0.1437    0.1564      (----------*----------)
STH Sn 3    3    0.0256    0.0177  (----------*----------)
                                   ---------+---------+---------+-------
Pooled StDev =   0.1999                   0.00      0.25      0.50
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3 0.0000530 0.0000177     0.67    0.588
Error      11 0.0002897 0.0000263
Total      14 0.0003427
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
Cs (H)      5  0.007528  0.001899           (----------*----------)
STH Cs 1    4  0.003908  0.001592   (----------*-----------)
STH Cs 2    3  0.008590  0.008766         (-------------*------------)
STH Cs 3    3  0.008387  0.007549         (-------------*------------)
                                   ----+---------+---------+---------+--
Pooled StDev = 0.005132             0.0000    0.0050    0.0100    0.0150
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS        MS        F        P
Factor        3    0.1704    0.0568     3.17    0.068
Error        11    0.1969    0.0179
Total        14    0.3673
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean     StDev  ------+---------+---------+---------+
La (H)        5    0.3076    0.2138                   (--------*-------)
STH La 1      4    0.0775    0.0393   (---------*---------)
STH La 2      3    0.0843    0.0486  (-----------*----------)
STH La 3      3    0.0843    0.0486  (-----------*----------)
                                     ------+---------+---------+---------+
Pooled StDev =     0.1338                0.00      0.15      0.30      0.45
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS        MS        F        P
Factor        3    0.3745    0.1248     1.53    0.262
Error        11    0.8976    0.0816
Total        14    1.2720
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean     StDev  -+---------+---------+---------+-----
Ce (H)        5    0.3519    0.3281              (---------*--------)
STH Ce 1      4    0.0453    0.0275    (----------*---------)
STH Ce 2      3    0.0610    0.0711   (-----------*-----------)
STH Ce 3      3    0.3926    0.4767             (-----------*-----------)
                                     -+---------+---------+---------+-----
Pooled StDev =     0.2857          -0.30      0.00      0.30      0.60
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS        MS        F        P
Factor        3  0.003379  0.001126     1.53    0.262
Error        11  0.008115  0.000738
Total        14  0.011495
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level         N      Mean     StDev  ---------+---------+---------+-------
Pr (H)        5   0.03452   0.03049            (--------*-------)
STH Pr 1      4   0.00508   0.00307   (---------*---------)
STH Pr 2      3   0.00878   0.01018  (-----------*----------)
STH Pr 3      3   0.03961   0.04561            (----------*-----------)
                                     ---------+---------+---------+-------
Pooled StDev =    0.02716                 0.000     0.030     0.060
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS         MS          F        P
Factor        3   0.04797    0.01599       1.75    0.215
Error        11   0.10070    0.00915
Total        14   0.14867
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  ---------+---------+---------+-------
Nd (H)        5   0.12904    0.10710              (---------*--------)
STH Nd 1      4   0.01820    0.00554  (----------*---------)
STH Nd 2      3   0.03318    0.04168  (-----------*-----------)
STH Nd 3      3   0.14923    0.16007              (-----------*-----------)
                                      ---------+---------+---------+-------
Pooled StDev =    0.09568                     0.00      0.10      0.20
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF         SS          MS          F        P
Factor        3   0.000767    0.000256       2.47    0.116
Error        11   0.001137    0.000103
Total        14   0.001904
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  ------+---------+---------+---------+
Sm (H)        5   0.02005    0.00904                (--------*-------)
STH Sm 1      4   0.00466    0.00116   (--------*--------)
STH Sm 2      3   0.00796    0.00776    (-----------*---------)
STH Sm 3      3   0.02051    0.01851             (-----------*----------)
                                      ------+---------+---------+---------+
Pooled StDev =    0.01017                 0.000     0.012     0.024     0.036
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS           F        P
Factor        3 0.0001166 0.0000389        1.36    0.306
Error        11 0.0003148 0.0000286
Total        14 0.0004314
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean      StDev  -+---------+---------+---------+-----
Eu (H)        5  0.007594   0.008028                  (---------*----------)
STH Eu 1      4  0.000410   0.000820  (-----------*-----------)
STH Eu 2      3  0.003590   0.004352      (-------------*-------------)
STH Eu 3      3  0.003777   0.002925      (--------------*------------)
                                      -+---------+---------+---------+-----
Pooled StDev = 0.005349            -0.0050    0.0000    0.0050    0.0100
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3 0.0000170 0.0000057     1.38    0.299
Error       11 0.0000450 0.0000041
Total       14 0.0000620
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev -------+---------+---------+---------
Tb (H)       5  0.001893  0.001003       (-------*-------)
STH Tb 1     4  0.000624  0.000788  (-------*--------)
STH Tb 2     3  0.003417  0.003867          (----------*---------)
STH Tb 3     3  0.003078  0.002149         (---------*----------)
                                   -------+---------+---------+---------
Pooled StDev = 0.002023                 0.0000    0.0025    0.0050
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3  0.001048  0.000349     1.57    0.251
Error       11  0.002441  0.000222
Total       14  0.003489
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev --------+---------+---------+--------
Gd (H)       5   0.02461   0.01246               (--------*---------)
STH Gd 1     4   0.00456   0.00106 (----------*----------)
STH Gd 2     3   0.01540   0.01585       (-----------*------------)
STH Gd 3     3   0.02363   0.02563            (------------*-----------)
                                   --------+---------+---------+--------
Pooled StDev =   0.01490                  0.000     0.015     0.030
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS        MS        F        P
Factor       3 0.0003185 0.0001062     1.52    0.264
Error       11 0.0007680 0.0000698
Total       14 0.0010865
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev --------+---------+---------+--------
Dy (H)       5  0.014796  0.008002                (---------*----------)
STH Dy 1     4  0.002975  0.000706 (-----------*----------)
STH Dy 2     3  0.011290  0.014212          (------------*------------)
STH Dy 3     3  0.010667  0.007294         (------------*-------------)
                                   --------+---------+---------+--------
Pooled StDev = 0.008356                  0.0000    0.0080    0.0160
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0000052 0.0000017        0.17    0.915
Error       11 0.0001137 0.0000103
Total       14 0.0001189
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean      StDev  -----+---------+---------+---------+-
Ho (H)       5  0.002904   0.001718      (----------*---------)
STH Ho 1     4  0.002569   0.004066    (-----------*----------)
STH Ho 2     3  0.004200   0.004825       (-------------*-------------)
STH Ho 3     3  0.002761   0.001692   (------------*-------------)
                                     -----+---------+---------+---------+-
Pooled StDev = 0.003215                 0.0000    0.0030    0.0060    0.0090
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0000852 0.0000284        0.84    0.500
Error       11 0.0003717 0.0000338
Total       14 0.0004569
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean      StDev  ------+---------+---------+---------+
Er (H)       5  0.006454   0.003824         (---------*--------)
STH Er 1     4  0.002850   0.001126  (----------*---------)
STH Er 2     3  0.009837   0.011906            (-----------*------------)
STH Er 3     3  0.005680   0.003598    (------------*------------)
                                     ------+---------+---------+---------+
Pooled StDev = 0.005813                  0.0000    0.0060    0.0120    0.0180
```

One-way Analysis of Variance

```
Analysis of Variance
Source      DF        SS         MS          F        P
Factor       3 0.0000081 0.0000027        2.18    0.148
Error       11 0.0000136 0.0000012
Total       14 0.0000217
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level        N      Mean      StDev  -------+---------+---------+---------
Tm (H)       5  0.000584   0.000594      (------*------)
STH Tm 1     4  0.000210   0.000243  (-------*---------)
STH Tm 2     3  0.002267   0.002355              (---------*---------)
STH Tm 3     3  0.001085   0.000689      (---------*---------)
                                     -------+---------+---------+---------
Pooled StDev = 0.001113                   0.0000    0.0015    0.0030
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3 0.0001224 0.0000408       1.32    0.318
Error        11 0.0003400 0.0000309
Total        14 0.0004624
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  ---------+---------+---------+-------
Yb (H)        5  0.005616  0.002658           (---------*---------)
STH Yb 1      4  0.001171  0.000424   (----------*----------)
STH Yb 2      3  0.009150  0.012439              (------------*------------)
STH Yb 3      3  0.002960  0.000941    (------------*------------)
                                     ---------+---------+---------+-------
Pooled StDev = 0.005560                    0.0000    0.0060    0.0120
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3 0.0000147 0.0000049       1.99    0.174
Error        11 0.0000270 0.0000025
Total        14 0.0000417
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  ------+---------+---------+---------+
Lu (H)        5  0.001206  0.000645      (--------*--------)
STH Lu 1      4  0.000640  0.000253   (-------*--------)
STH Lu 2      3  0.003393  0.003478              (---------*---------)
STH Lu 3      3  0.001085  0.000689   (----------*---------)
                                     ------+---------+---------+---------+
Pooled StDev = 0.001567                 0.0000    0.0020    0.0040    0.0060
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS          MS          F        P
Factor        3  0.000348   0.000116      0.42    0.744
Error        11  0.003064   0.000279
Total        14  0.003412
                                     Individual 95% CIs For Mean
                                     Based on Pooled StDev
Level         N      Mean     StDev  ----+---------+---------+---------+--
Hf (H)        5   0.01459   0.02566              (----------*----------)
STH Hf 1      4   0.00783   0.01060        (------------*-----------)
STH Hf 2      3   0.00838   0.00675      (--------------*-------------)
STH Hf 3      3   0.00113   0.00123   (-------------*-------------)
                                     ----+---------+---------+---------+--
Pooled StDev =    0.01669             -0.015     0.000     0.015     0.030
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS        F        P
Factor      3 0.0000186 0.0000062      2.12    0.156
Error      11 0.0000322 0.0000029
Total      14 0.0000507
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean      StDev  -----+---------+---------+---------+-
Ta (H)      5  0.000691   0.000478  (-------*--------)
STH Ta 1    4  0.000950   0.000634  (---------*---------)
STH Ta 2    3  0.003657   0.003737              (----------*----------)
STH Ta 3    3  0.001288   0.001026   (---------*----------)
                                    -----+---------+---------+---------+-
Pooled StDev = 0.001710                0.0000    0.0020    0.0040    0.0060
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS        F        P
Factor      3     274.1       91.4     3.57    0.050
Error      11     281.1       25.6
Total      14     555.2
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean      StDev  ------+---------+---------+---------+
W (H)       5     3.690      2.716      (------*-------)
STH W  1    4     1.935      0.884   (-------*-------)
STH W  2    3    13.807      9.511                 (---------*--------)
STH W  3    3     5.473      5.847      (---------*--------)
                                    ------+---------+---------+---------+
Pooled StDev =    5.055                  0.0       7.0      14.0      21.0
```

One-way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS        F        P
Factor      3 0.0000297 0.0000099      1.18    0.363
Error      11 0.0000927 0.0000084
Total      14 0.0001224
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean      StDev  -+---------+---------+---------+-----
Tl (H)      5  0.007988   0.001892          (---------*---------)
STH Tl 1    4  0.006062   0.001519   (---------*----------)
STH Tl 2    3  0.008907   0.005404          (------------*-----------)
STH Tl 3    3  0.010027   0.002554              (-----------*-------------)
                                    -+---------+---------+---------+-----
Pooled StDev = 0.002903             0.0030    0.0060    0.0090    0.0120
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS        MS          F        P
Factor        3  0.000890  0.000297       1.48    0.273
Error        11  0.002202  0.000200
Total        14  0.003092
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean     StDev   ------+---------+---------+---------+
Bi (H)        5   0.02406   0.00971               (--------*--------)
STH Bi 1      4   0.00793   0.00268    (---------*----------)
STH Bi 2      3   0.02379   0.03001             (-----------*-----------)
STH Bi 3      3   0.00938   0.00102   (-----------*-----------)
                                      ------+---------+---------+---------+
Pooled StDev =   0.01415                  0.000     0.015     0.030     0.045
```

One-way Analysis of Variance

```
Analysis of Variance
Source       DF        SS        MS          F        P
Factor        3 0.0001340 0.0000447       1.25    0.339
Error        11 0.0003930 0.0000357
Total        14 0.0005270
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean     StDev   -------+---------+---------+---------
Th (H)        5  0.009482  0.005525               (---------*---------)
STH Th 1      4  0.002716  0.002619    (----------*---------)
STH Th 2      3  0.005927  0.007958      (------------*------------)
STH Th 3      3  0.009963  0.007864            (------------*-----------)
                                      -------+---------+---------+---------
Pooled StDev = 0.005977                    0.0000    0.0060    0.0120
```

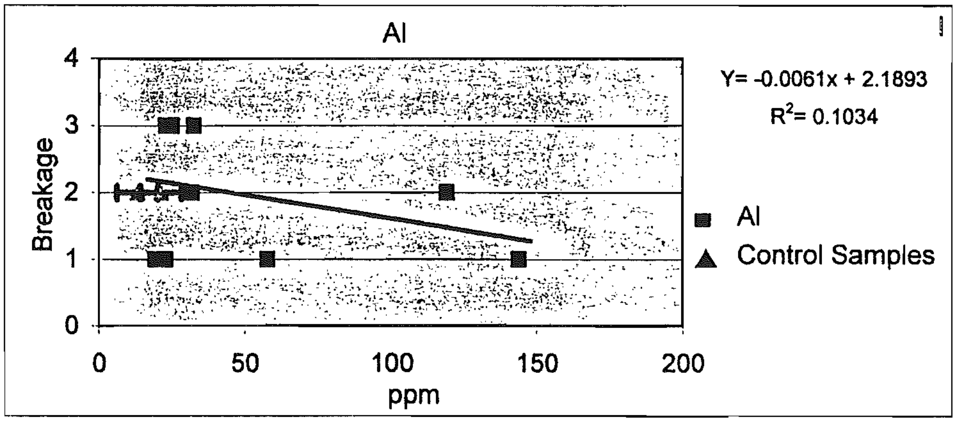
One-way Analysis of Variance

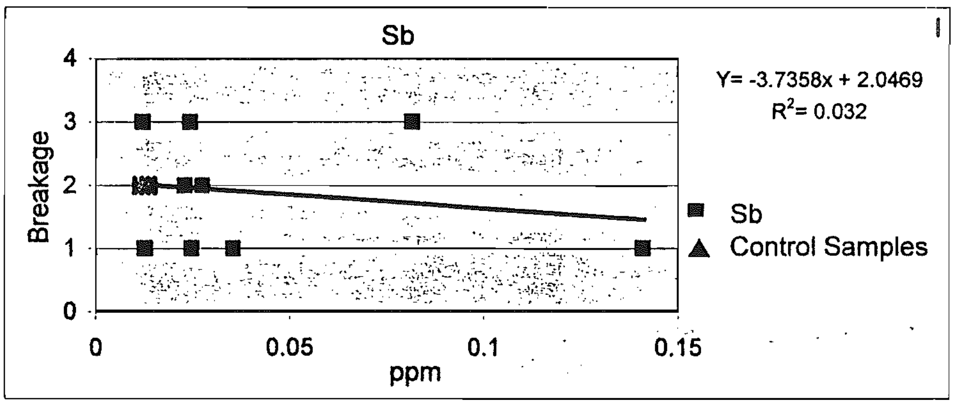
```
Analysis of Variance
Source       DF        SS        MS          F        P
Factor        3 0.0000306 0.0000102       0.62    0.618
Error        11 0.0001815 0.0000165
Total        14 0.0002120
                                      Individual 95% CIs For Mean
                                      Based on Pooled StDev
Level         N      Mean     StDev   -----+---------+---------+---------+-
U (H)         5  0.005310  0.001654            (---------*---------)
STH U   1     4  0.002623  0.001938   (-----------*----------)
STH U   2     3  0.006557  0.007460            (------------*------------)
STH U   3     3  0.005407  0.004897          (------------*-----------)
                                      -----+---------+---------+---------+-
Pooled StDev = 0.004062                 0.0000    0.0040    0.0080    0.0120
```

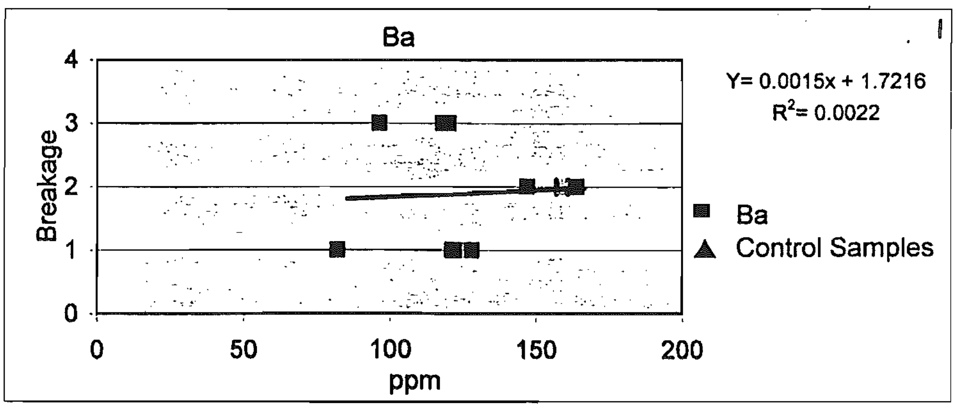
One-way Analysis of Variance

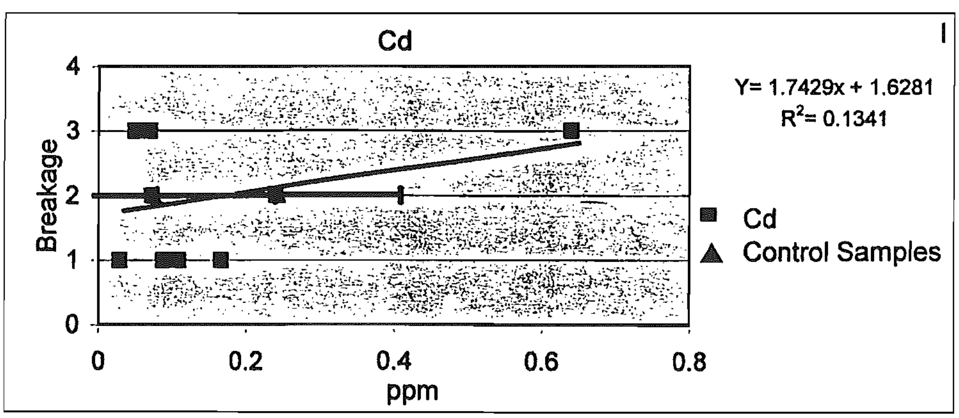
```
Analysis of Variance
Source     DF        SS        MS        F        P
Factor      3     1.990     0.663     1.63    0.239
Error      11     4.482     0.407
Total      14     6.472
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level          N      Mean     StDev  --------+---------+---------+--------
REE Health     5    0.9088    0.7179              (--------*--------)
REE S  1       4    0.1667    0.0742  (---------*---------)
REE S  2       3    0.2577    0.2512  (-----------*----------)
REE S  3       3    0.9704    1.0672            (-----------*----------)
                                      --------+---------+---------+--------
Pooled StDev =    0.6383                     0.00      0.70      1.40
```

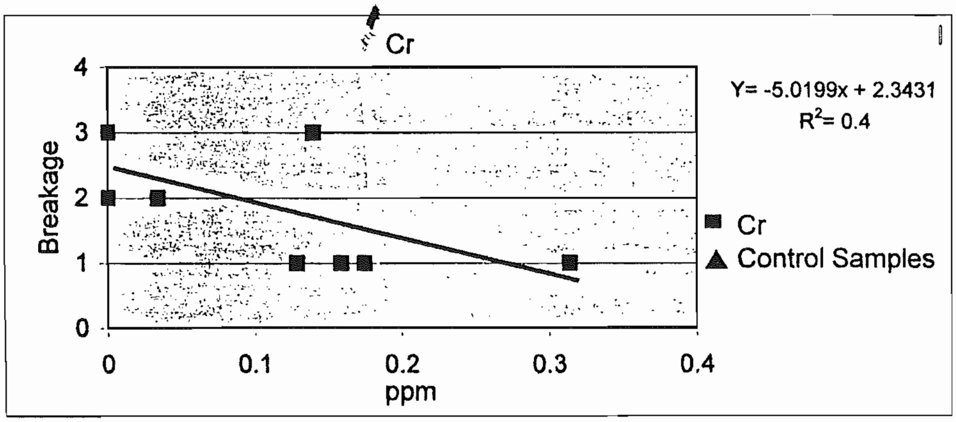
Appendix F: Correlation results for North of the Park: Breakage score Vs Elemental concentration (Control samples with 95% confidence included)

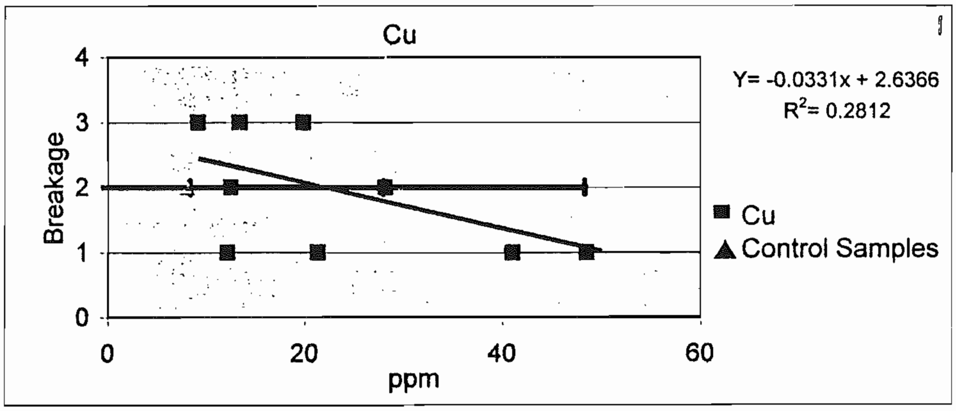

Al
Breakage
4
3
2
1
0
0
50
100
150
200
ppm
Y= -0.0061x + 2.1893
R2= 0.1034
Al
Control Samples

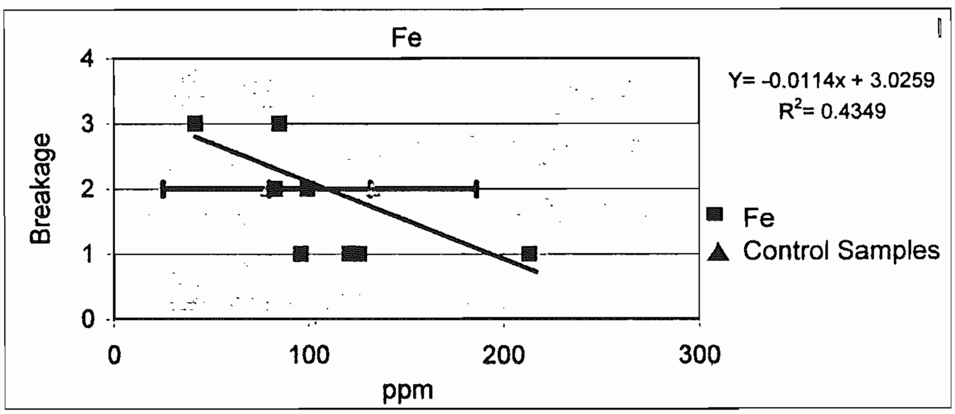

Sb
Breakage
4
3
2
1
0
0
0.05
0.1
0.15
ppm
Y= -3.7358x + 2.0469
R2= 0.032
Sb
Control Samples

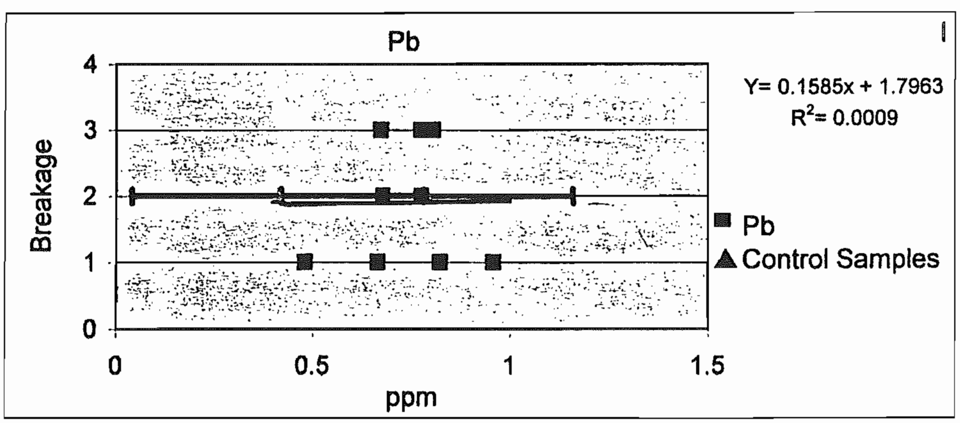

Ba
Breakage
4
3
2
1
0
0
50
100
150
200
ppm
Y= 0.0015x + 1.7216
R2= 0.0022
Ba
Control Samples

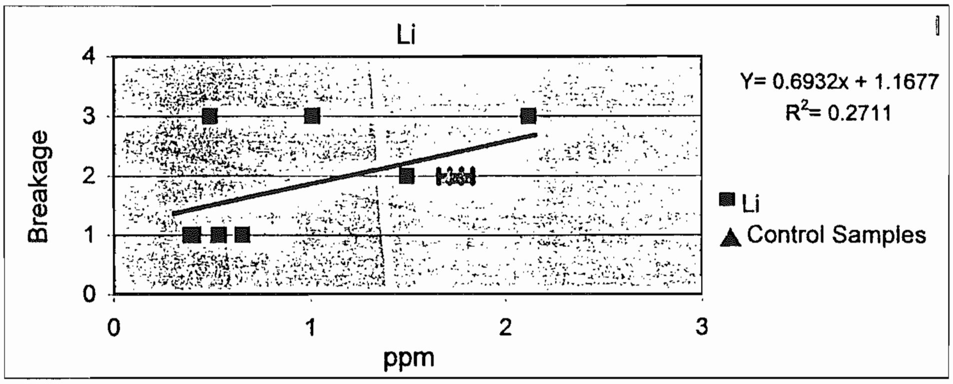

Cd
Breakage
4
3
2
1
0
0
0.2
0.4
0.6
0.8
ppm
Y= 1.7429x + 1.6281
R2= 0.1341
Cd
Control Samples

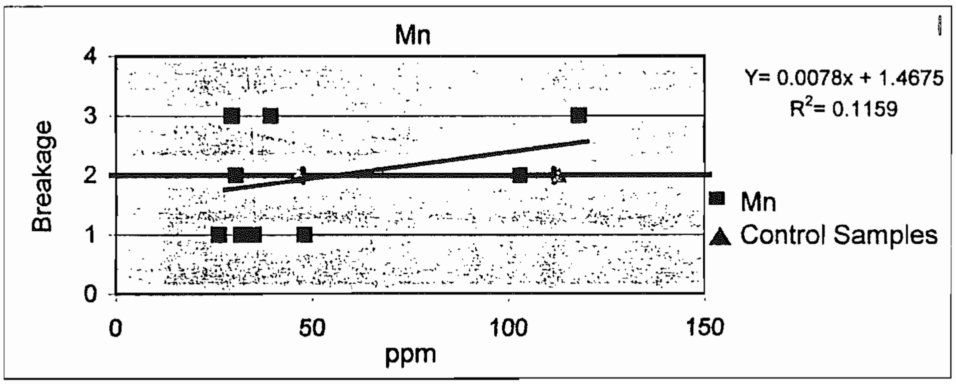

Cr
Breakage
ppm
Y= -5.0199x + 2.3431
R2= 0.4
Cr
Control Samples

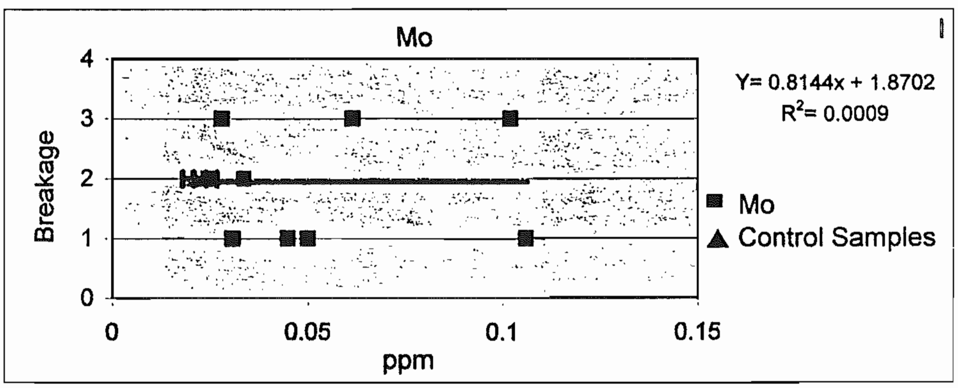

Cu
Breakage
ppm
Y= -0.0331x + 2.6366
R2= 0.2812
Cu
Control Samples

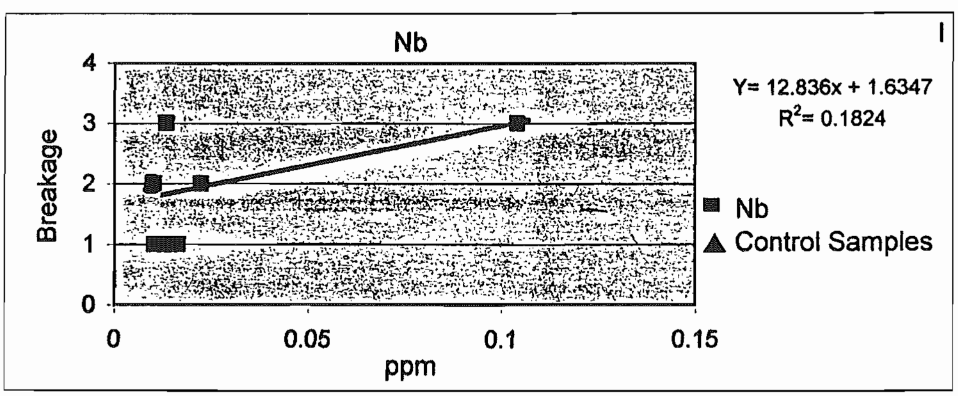

Fe
Breakage
ppm
Y= -0.0114x + 3.0259
R2= 0.4349
Fe
Control Samples

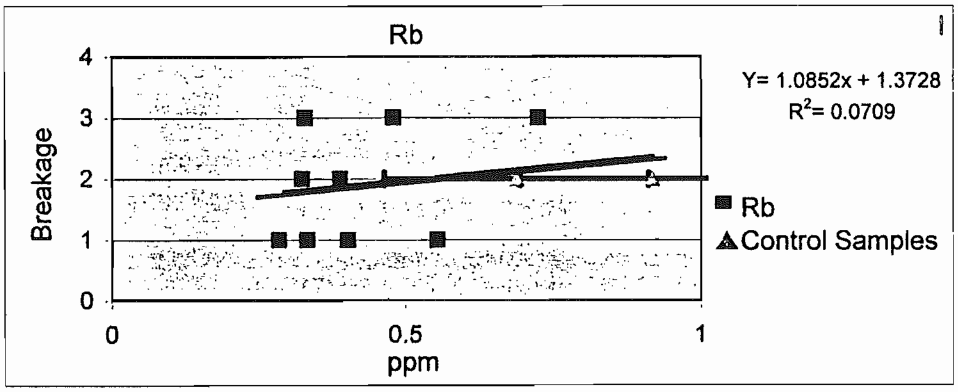

Pb
Breakage
ppm
Y= 0.1585x + 1.7963
R2= 0.0009
Pb
Control Samples

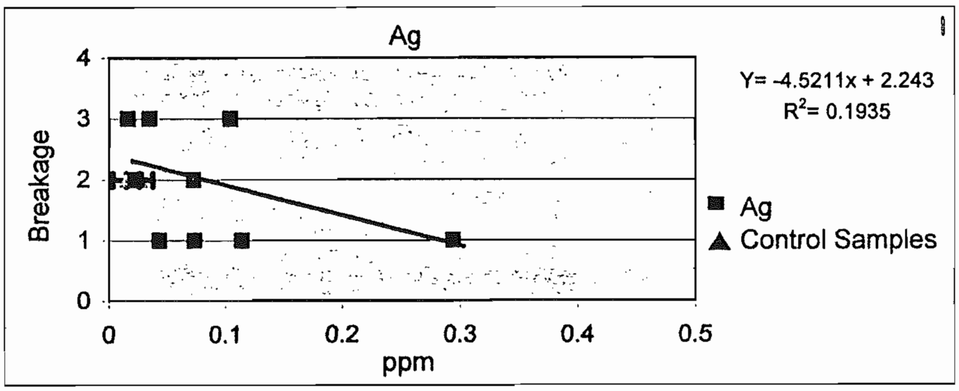

Li
Breakage
ppm
Y= 0.6932x + 1.1677
R2= 0.2711
Li
Control Samples

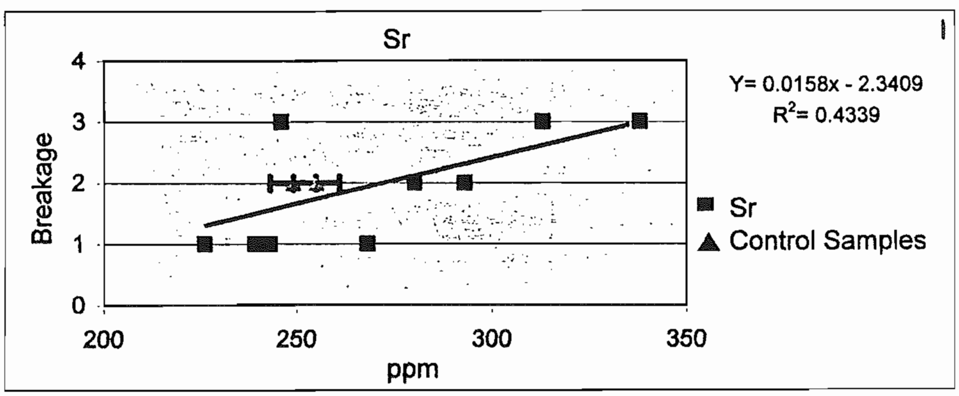

Mn
Breakage
ppm
Y= 0.0078x + 1.4675
R2= 0.1159
Mn
Control Samples

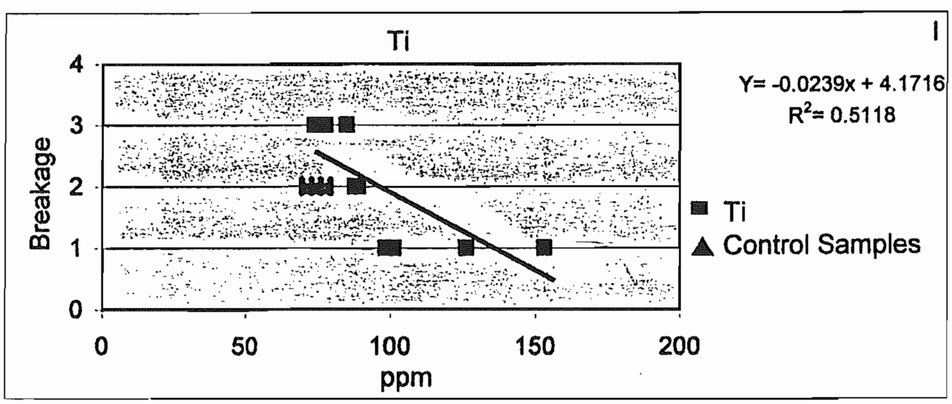

Mo
Breakage
ppm
Y= 0.8144x + 1.8702
R2= 0.0009
Mo
Control Samples

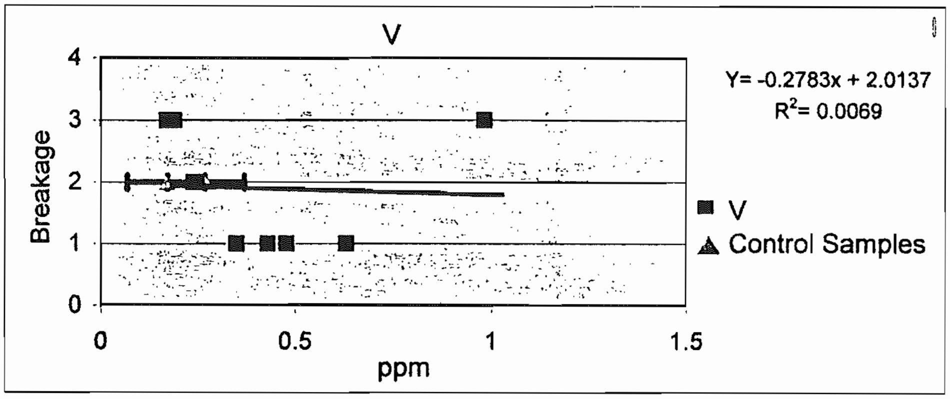

Nb
Breakage
ppm
Y= 12.836x + 1.6347
R2= 0.1824
Nb
Control Samples

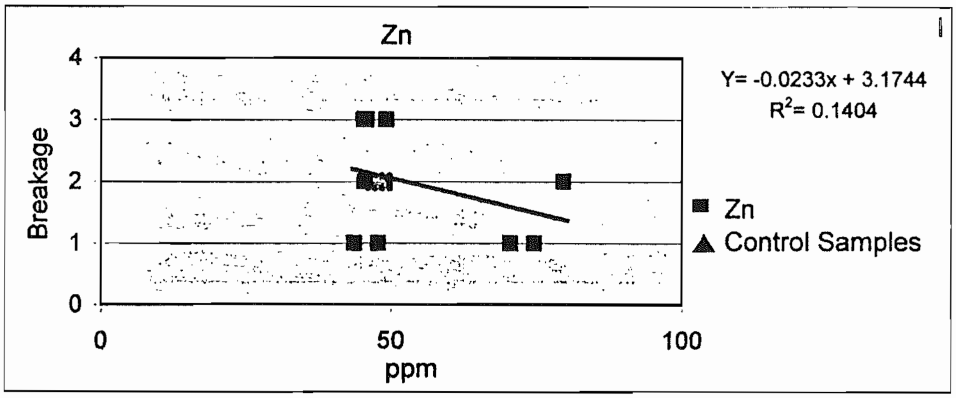

Rb
Breakage
ppm
Y= 1.0852x + 1.3728
R^2= 0.0709
Rb
Control Samples

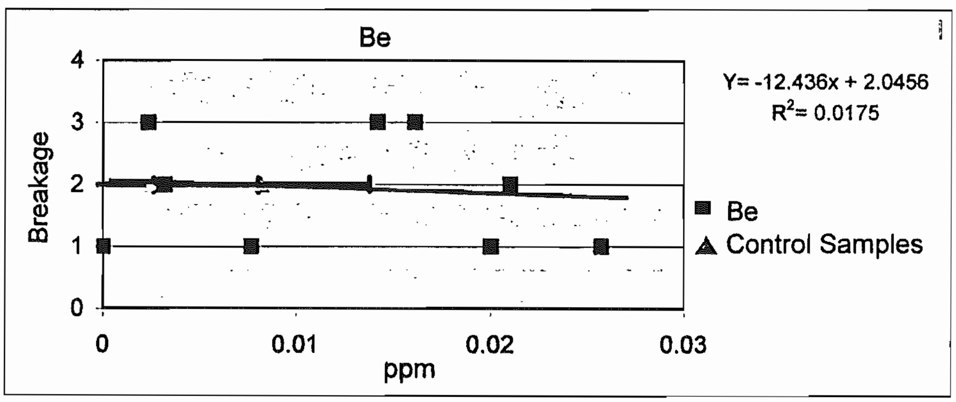

Ag
Breakage
ppm
Y= -4.5211x + 2.243
R^2= 0.1935
Ag
Control Samples

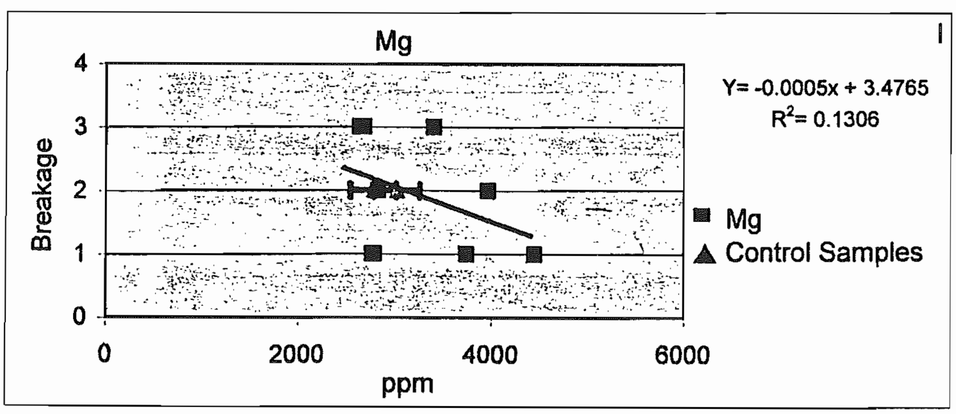

Sr
Breakage
ppm
Y= 0.0158x - 2.3409
R^2= 0.4339
Sr
Control Samples

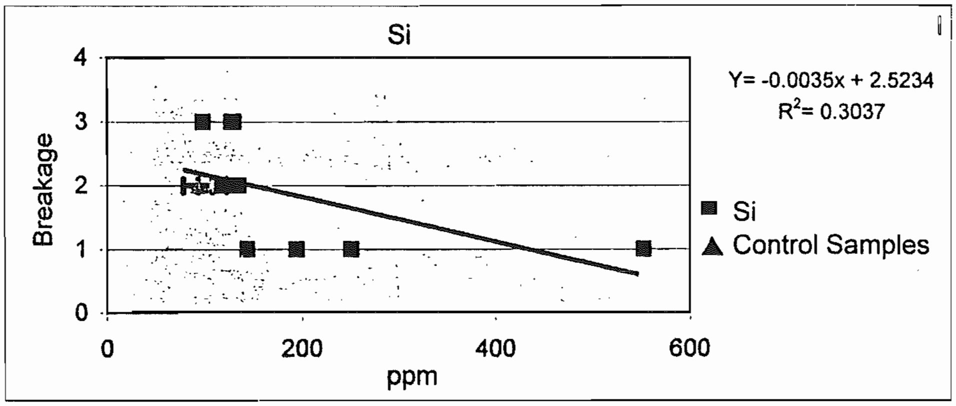

Ti
Breakage
ppm
Y= -0.0239x + 4.1716
R^2= 0.5118
Ti
Control Samples

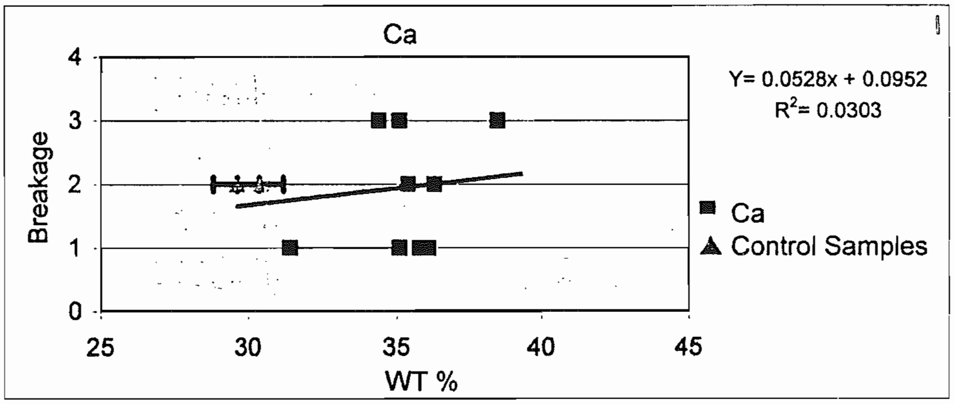

V
Y= -0.2783x + 2.0137
R^2= 0.0069
Breakage
ppm
V
Control Samples
0
0.5
1
1.5
4
3
2
1
0

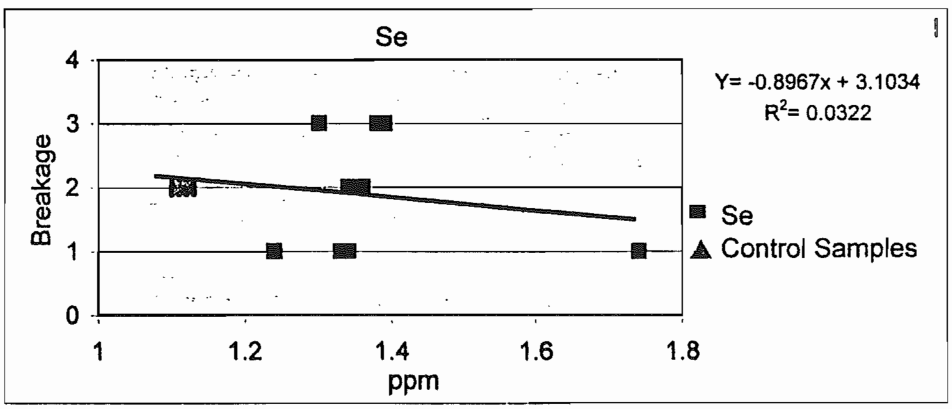

Zn
Y= -0.0233x + 3.1744
R^2= 0.1404
Breakage
ppm
Zn
Control Samples
0
50
100
4
3
2
1
0

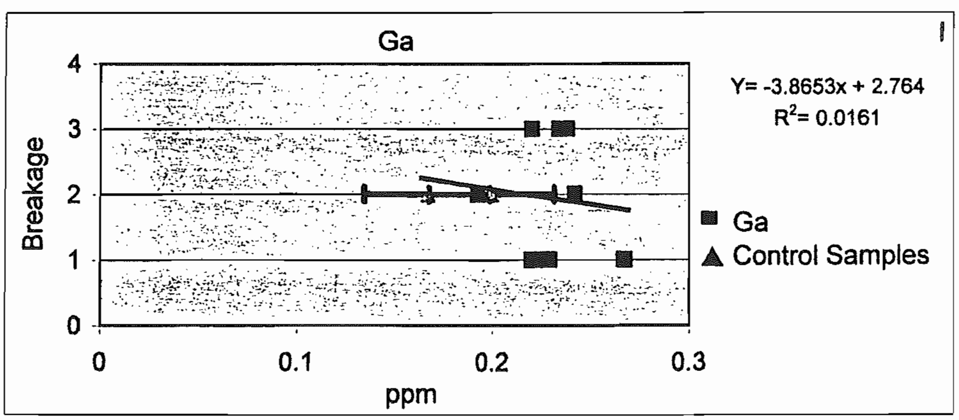

Be
Y= -12.436x + 2.0456
R^2= 0.0175
Breakage
ppm
Be
Control Samples
0
0.01
0.02
0.03
4
3
2
1
0

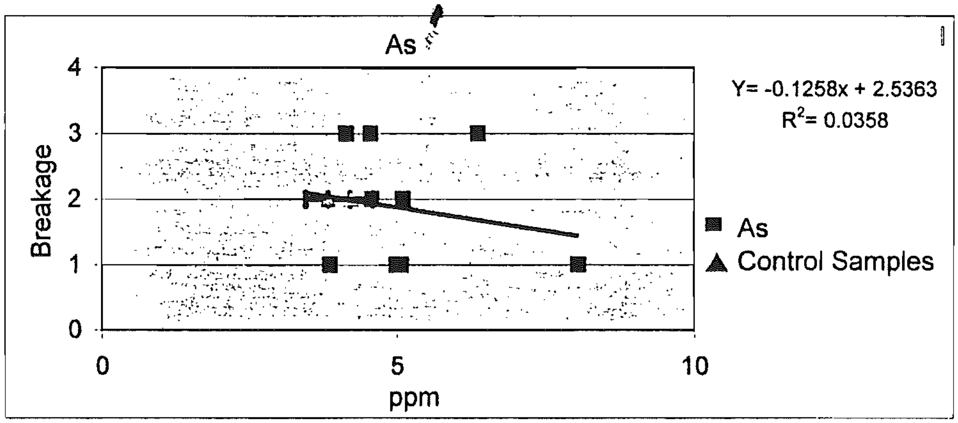

Mg
Y= -0.0005x + 3.4765
R^2= 0.1306
Breakage
ppm
Mg
Control Samples
0
2000
4000
6000
4
3
2
1
0

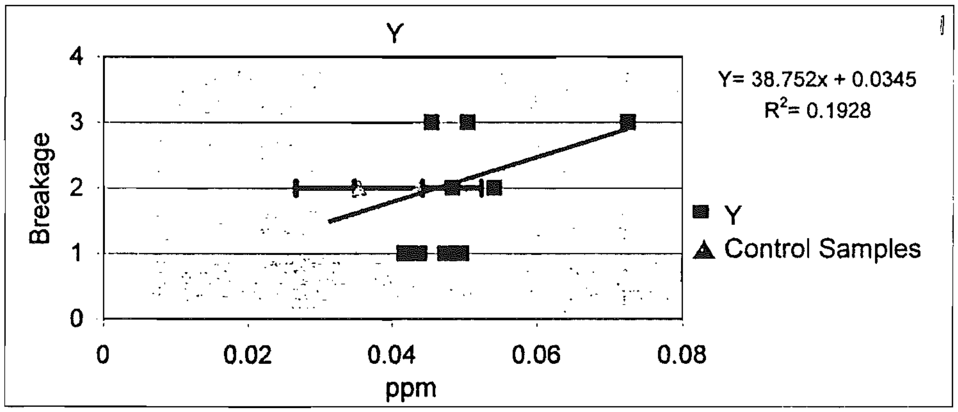

Si
Breakage
ppm
Y= -0.0035x + 2.5234
R2= 0.3037
Si
Control Samples

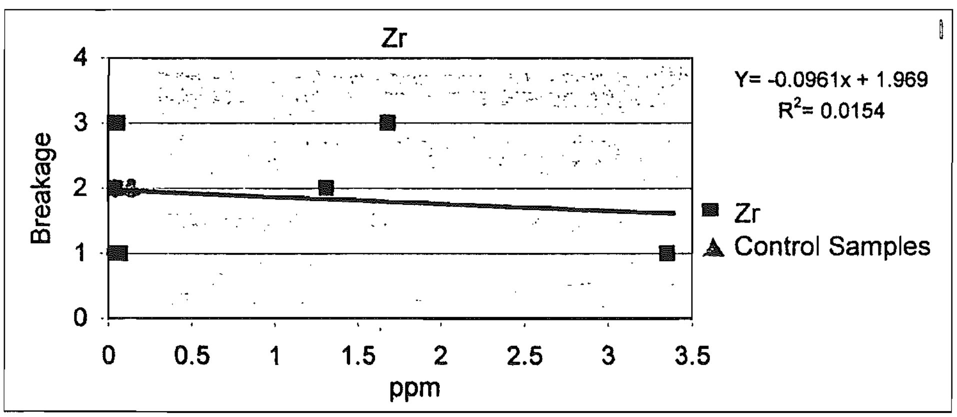

Ca
Breakage
WT %
Y= 0.0528x + 0.0952
R2= 0.0303
Ca
Control Samples

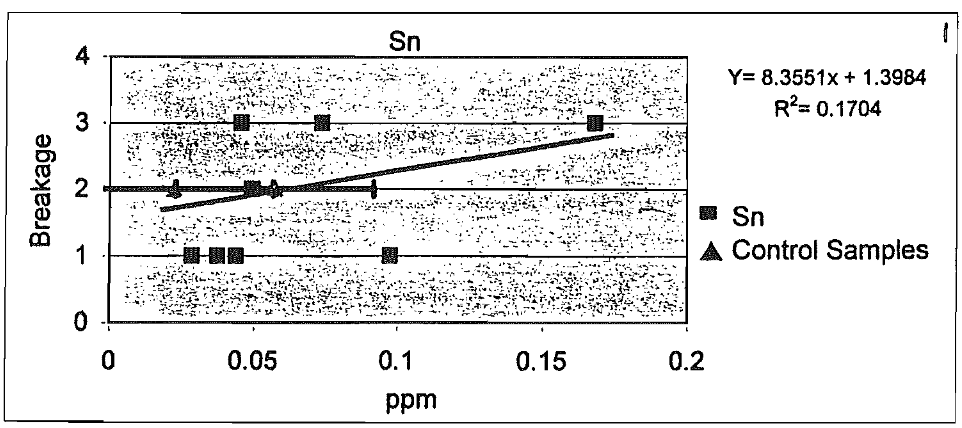

Se
Breakage
ppm
Y= -0.8967x + 3.1034
R2= 0.0322
Se
Control Samples

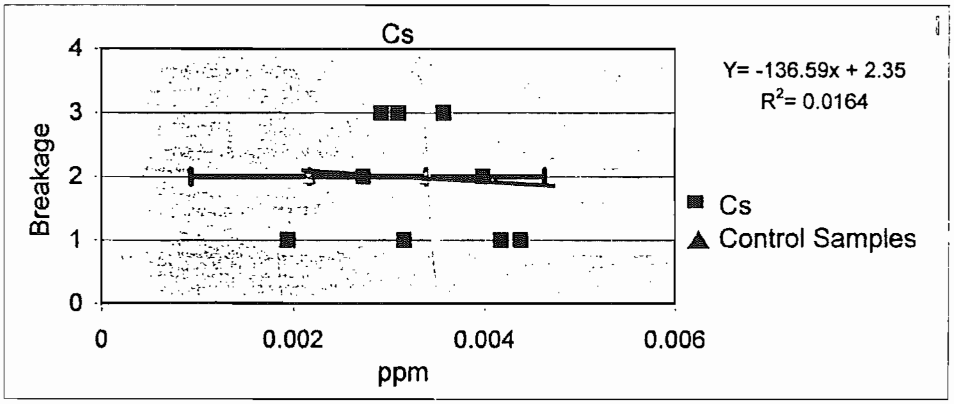

Ga
Breakage
ppm
Y= -3.8653x + 2.764
R2= 0.0161
Ga
Control Samples

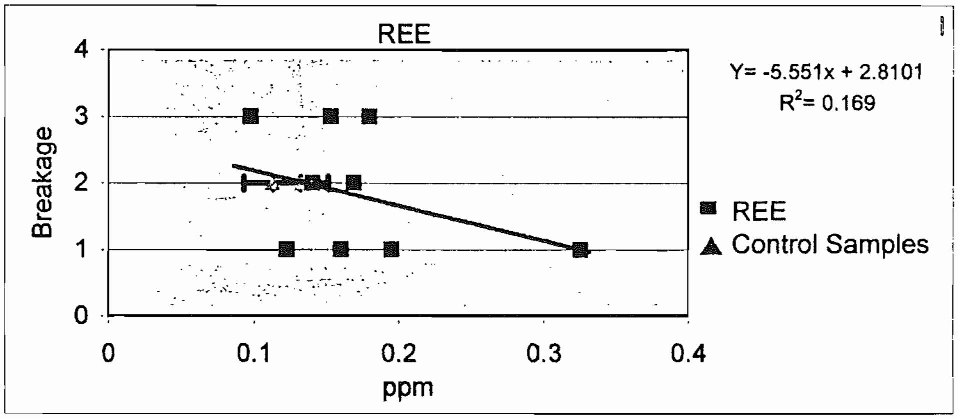

As
Breakage
ppm
0
5
10
4
3
2
1
Y= -0.1258x + 2.5363
R2= 0.0358
As
Control Samples

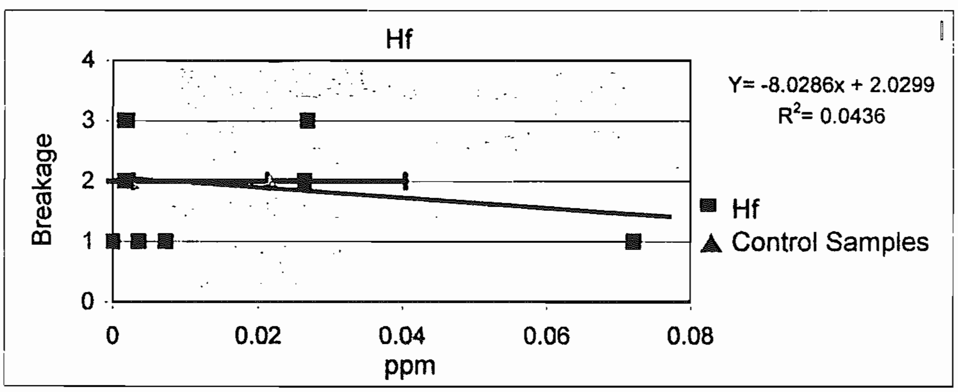

Y
Breakage
ppm
0
0.02
0.04
0.06
0.08
4
3
2
1
Y= 38.752x + 0.0345
R2= 0.1928
Y
Control Samples

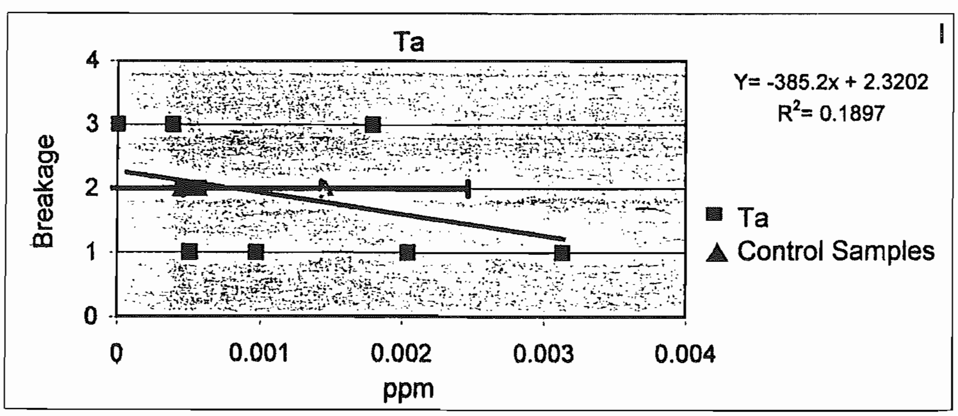

Zr
Breakage
ppm
0
0.5
1
1.5
2
2.5
3
3.5
4
Y= -0.0961x + 1.969
R2= 0.0154
Zr
Control Samples

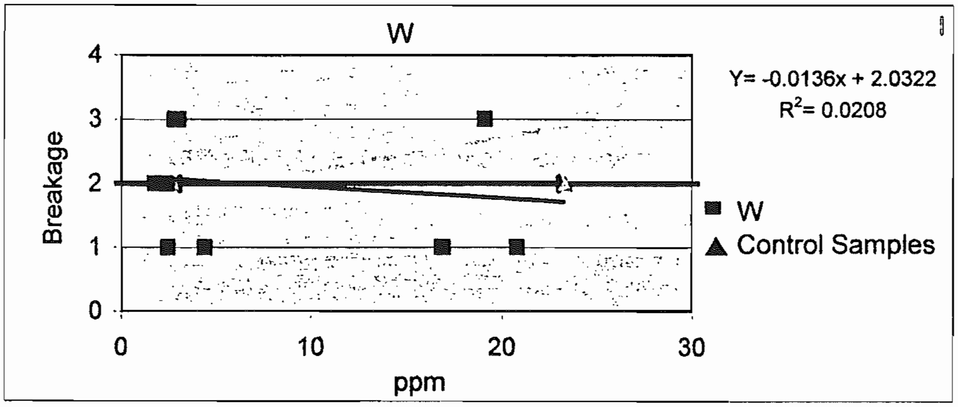

Sn
Breakage
ppm
0
0.05
0.1
0.15
0.2
4
3
2
1
Y= 8.3551x + 1.3984
R2= 0.1704
Sn
Control Samples

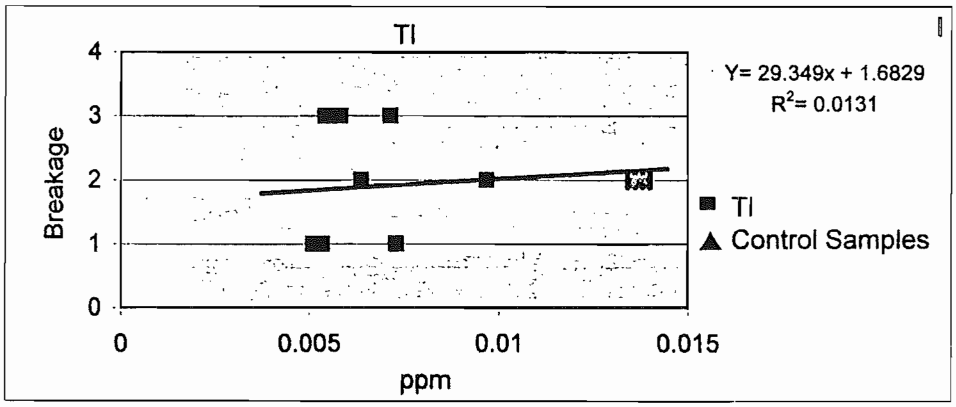

Cs
Y= -136.59x + 2.35
R2= 0.0164
Cs
Control Samples
Breakage
ppm
0
0.002
0.004
0.006
0
1
2
3
4

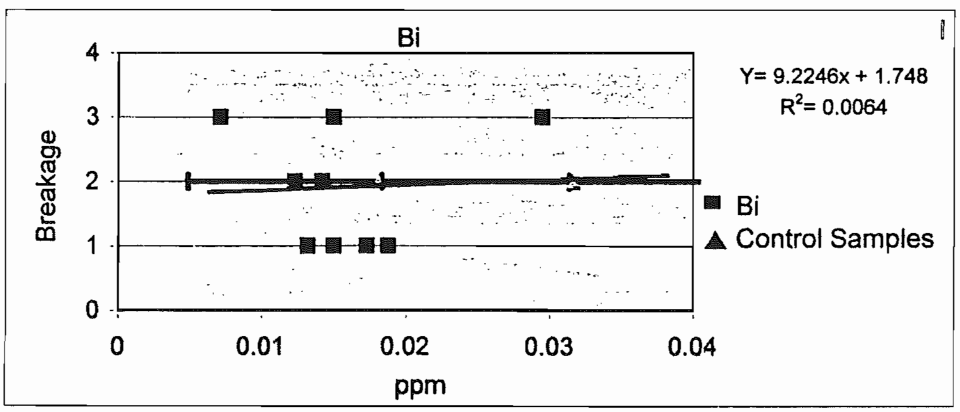

REE
Y= -5.551x + 2.8101
R2= 0.169
REE
Control Samples
Breakage
ppm
0
0.1
0.2
0.3
0.4
0
1
2
3
4

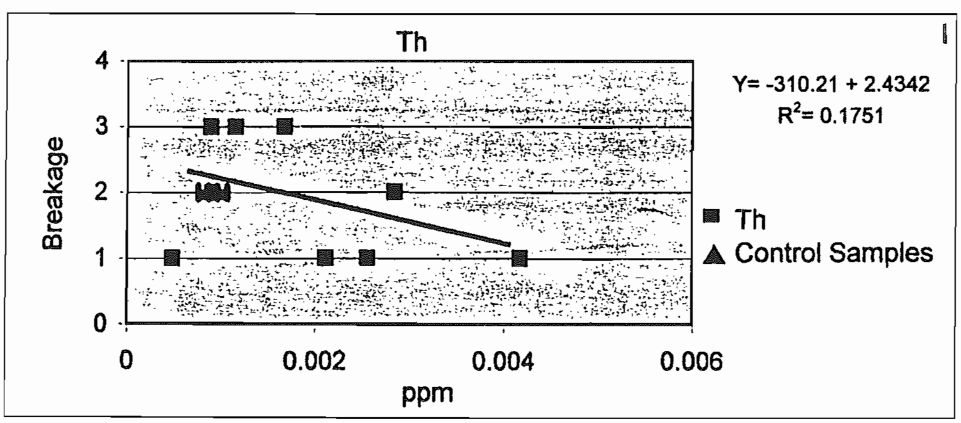

Hf
Y= -8.0286x + 2.0299
R2= 0.0436
Hf
Control Samples
Breakage
ppm
0
0.02
0.04
0.06
0.08
0
1
2
3
4

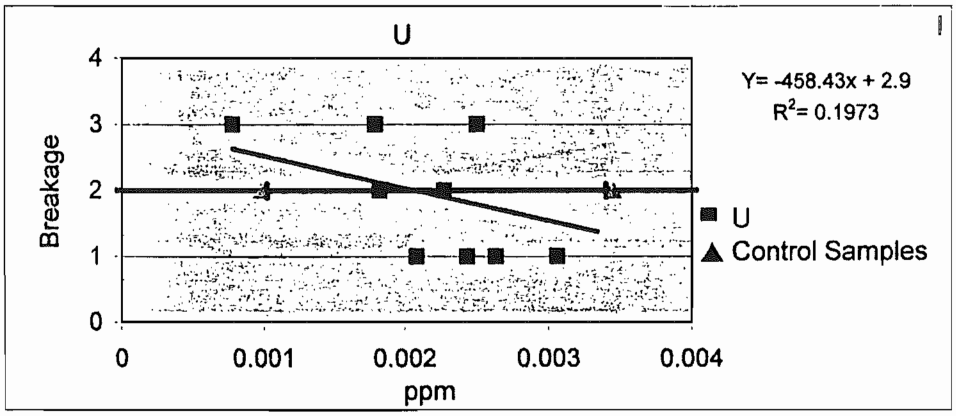

Ta
Y= -385.2x + 2.3202
R2= 0.1897
Ta
Control Samples
Breakage
ppm
0
0.001
0.002
0.003
0.004
0
1
2
3
4


W
Y= -0.0136x + 2.0322
R2= 0.0208
Breakage
ppm
W
Control Samples

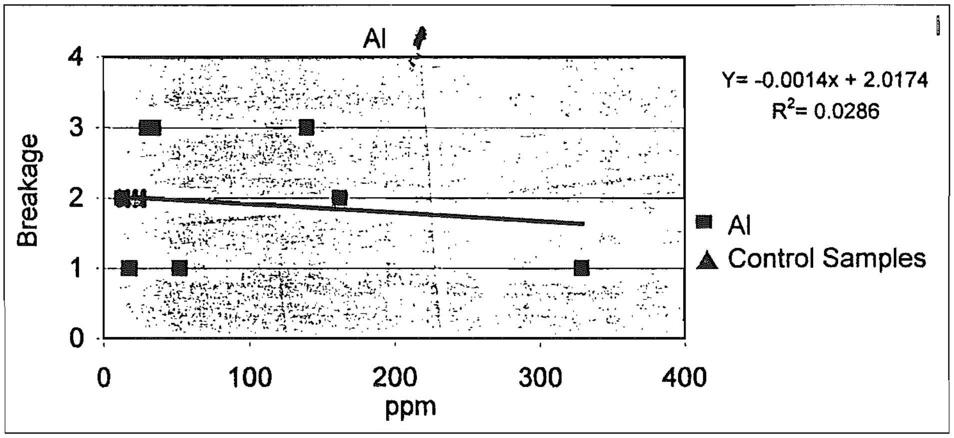

Tl
Y= 29.349x + 1.6829
R2= 0.0131
Breakage
ppm
Tl
Control Samples

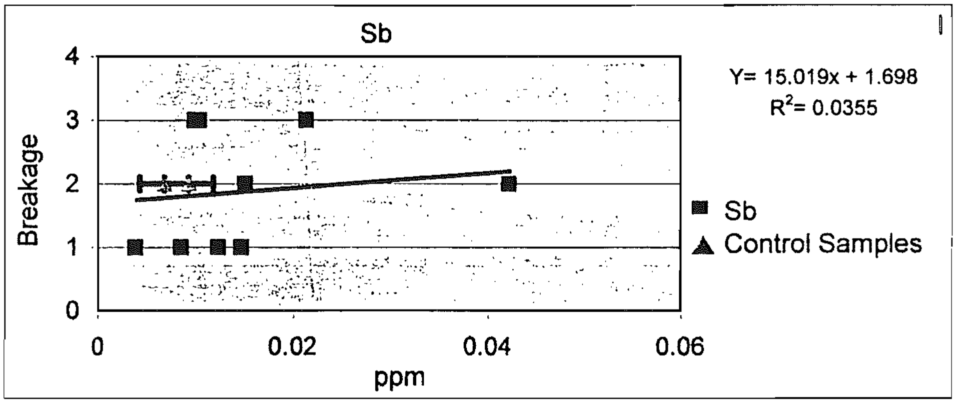

Bi
Y= 9.2246x + 1.748
R2= 0.0064
Breakage
ppm
Bi
Control Samples

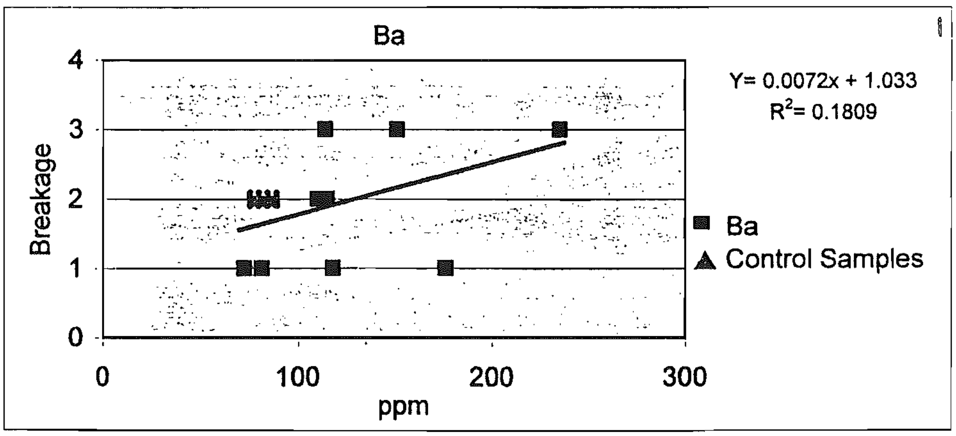

Th
Y= -310.21 + 2.4342
R2= 0.1751
Breakage
ppm
Th
Control Samples

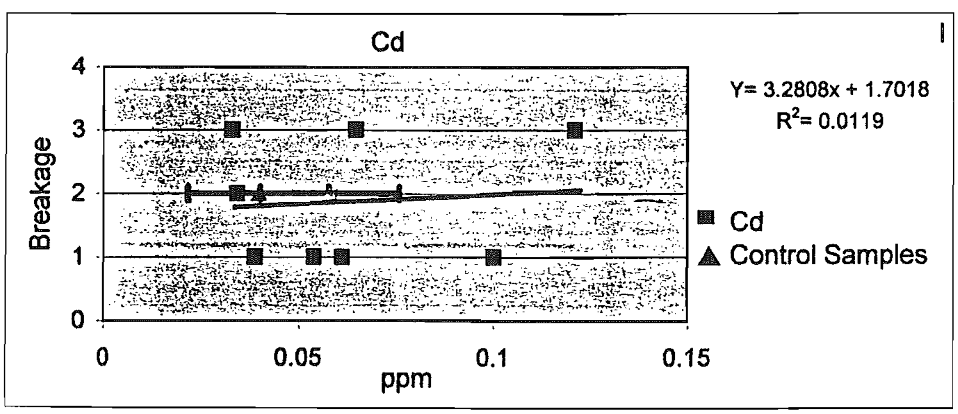

U
Y= -458.43x + 2.9
R^2= 0.1973
Breakage
4
3
2
1
0
0
0.001
0.002
0.003
0.004
ppm
U
Control Samples

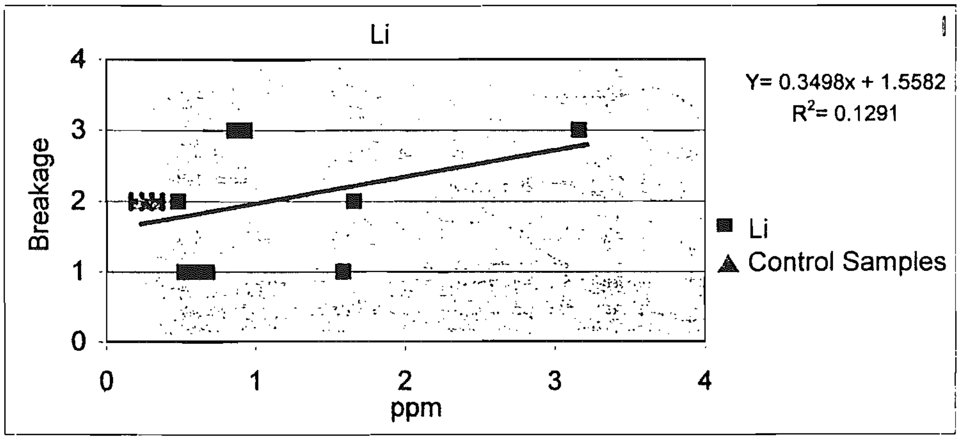
Appendix G: Correlation results for South of the Park: Breakage score Vs Elemental concentration (Control samples with 95% confidence included)

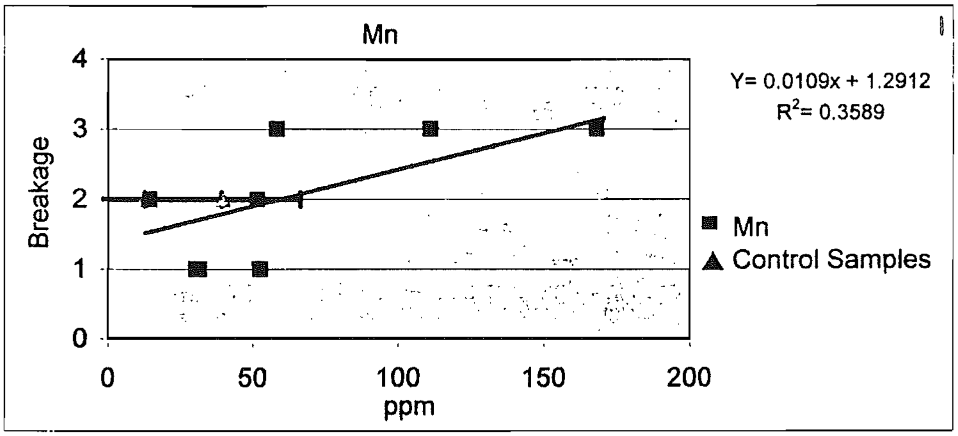

Al
Y= -0.0014x + 2.0174
R2= 0.0286
Breakage
ppm
Al
Control Samples

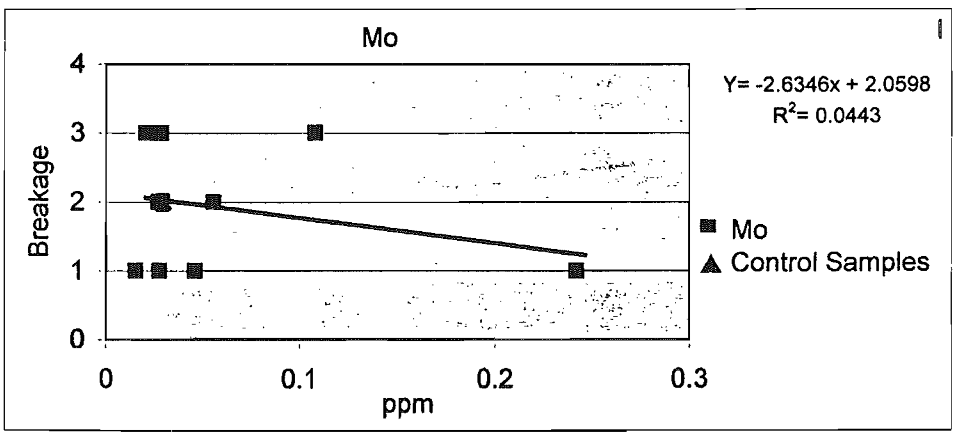

Sb
Y= 15.019x + 1.698
R2= 0.0355
Breakage
ppm
Sb
Control Samples

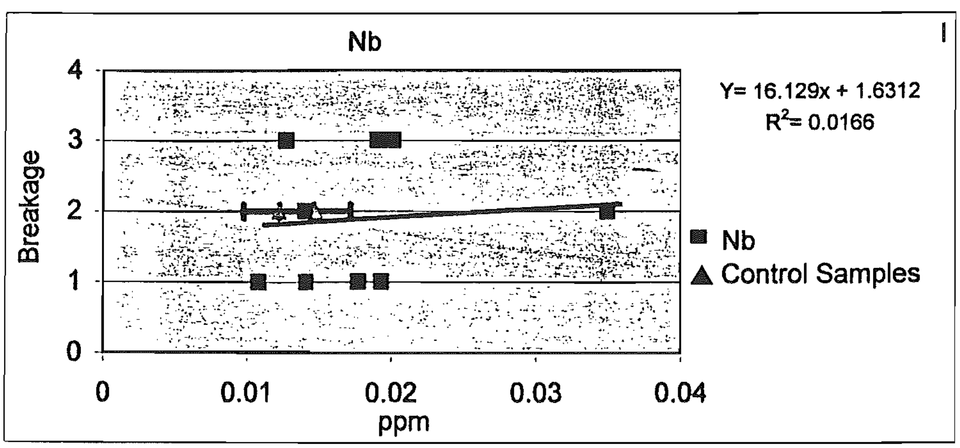

Ba
Y= 0.0072x + 1.033
R2= 0.1809
Breakage
ppm
Ba
Control Samples

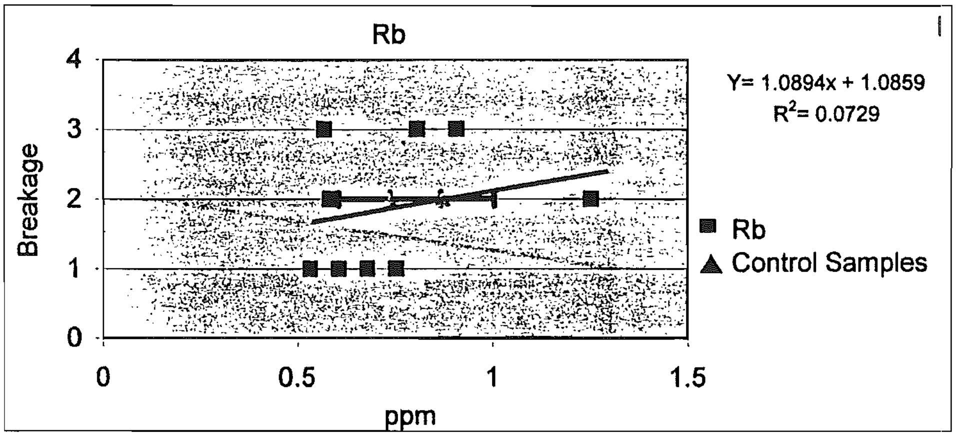

Cd
Y= 3.2808x + 1.7018
R2= 0.0119
Breakage
ppm
Cd
Control Samples

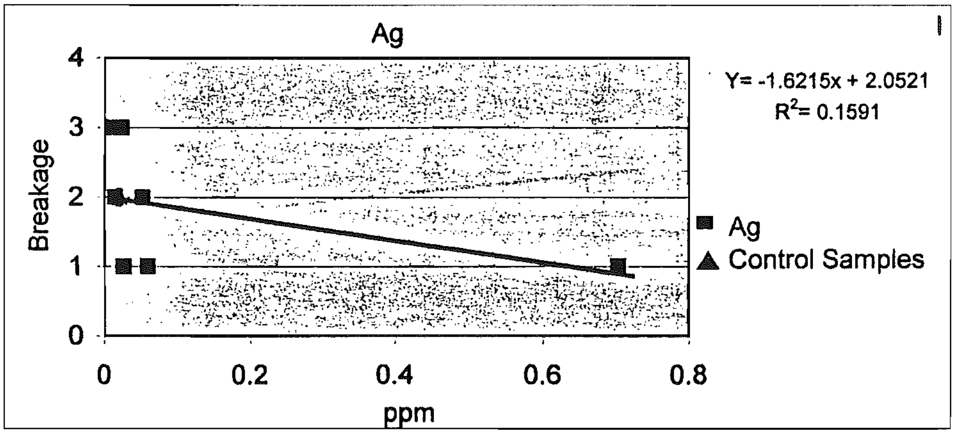

Li
Breakage
ppm
Y= 0.3498x + 1.5582
R^2= 0.1291
Li
Control Samples

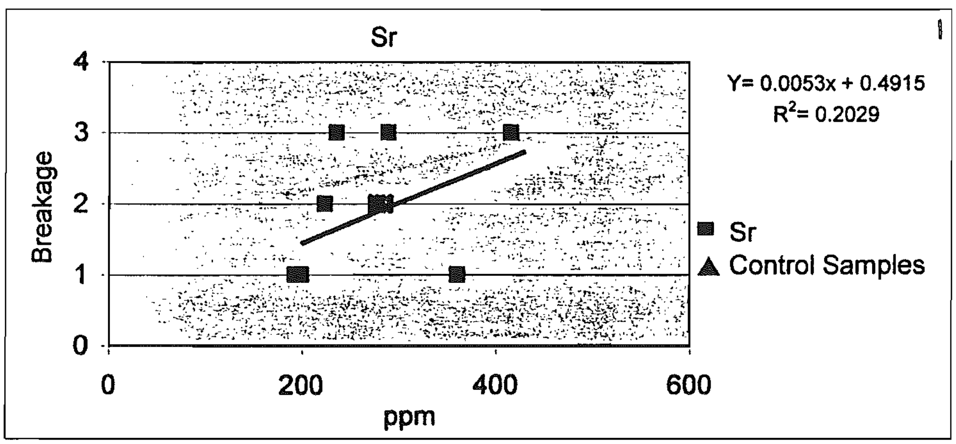

Mn
Breakage
ppm
Y= 0.0109x + 1.2912
R^2= 0.3589
Mn
Control Samples

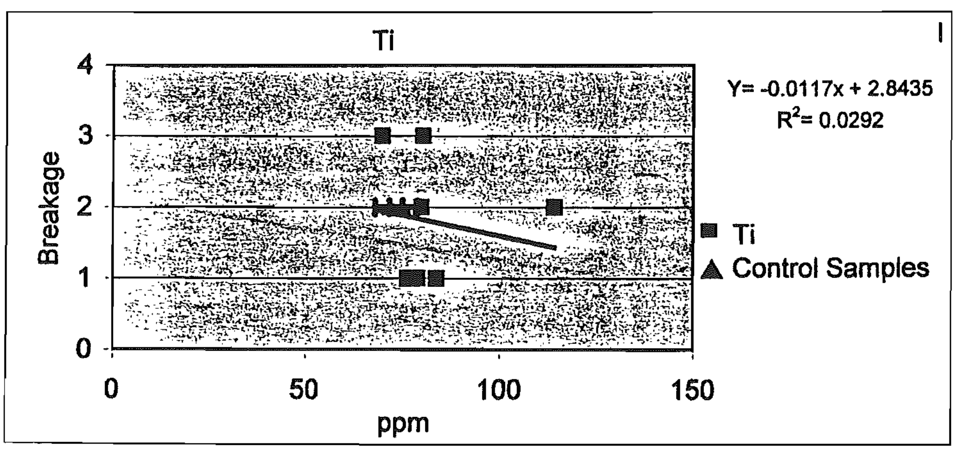

Mo
Breakage
ppm
Y= -2.6346x + 2.0598
R^2= 0.0443
Mo
Control Samples

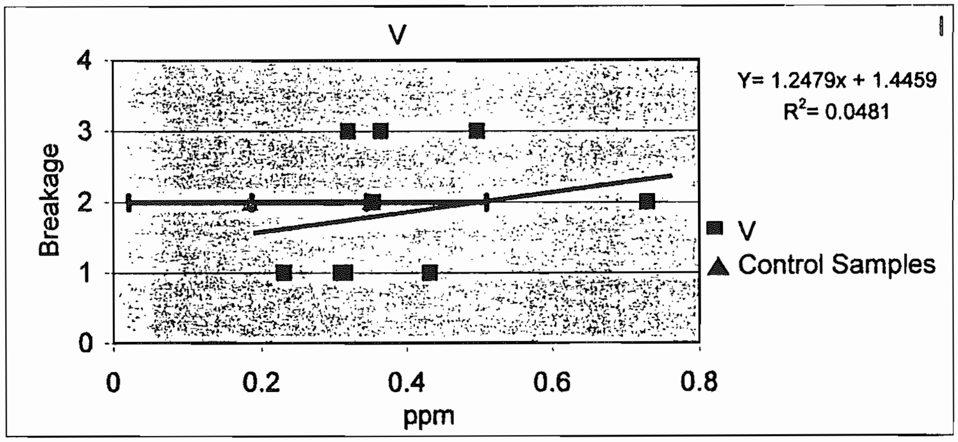

Nb
Breakage
ppm
Y= 16.129x + 1.6312
R^2= 0.0166
Nb
Control Samples

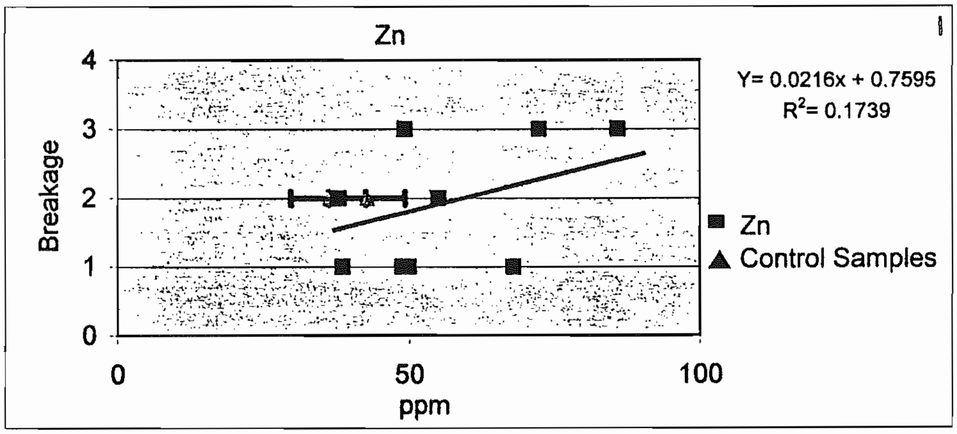

Rb
Y= 1.0894x + 1.0859
R^2= 0.0729
Breakage
4
3
2
1
0
0
0.5
1
1.5
ppm
Rb
Control Samples

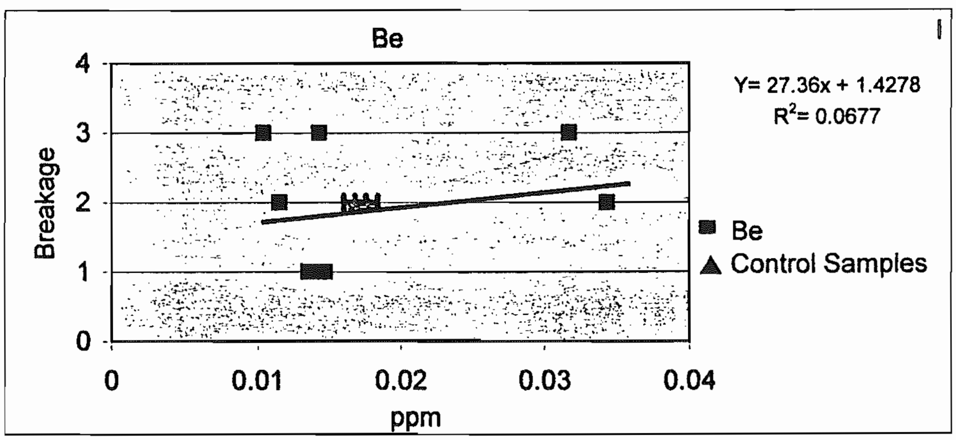

Ag
Y= -1.6215x + 2.0521
R^2= 0.1591
Breakage
4
3
2
1
0
0
0.2
0.4
0.6
0.8
ppm
Ag
Control Samples

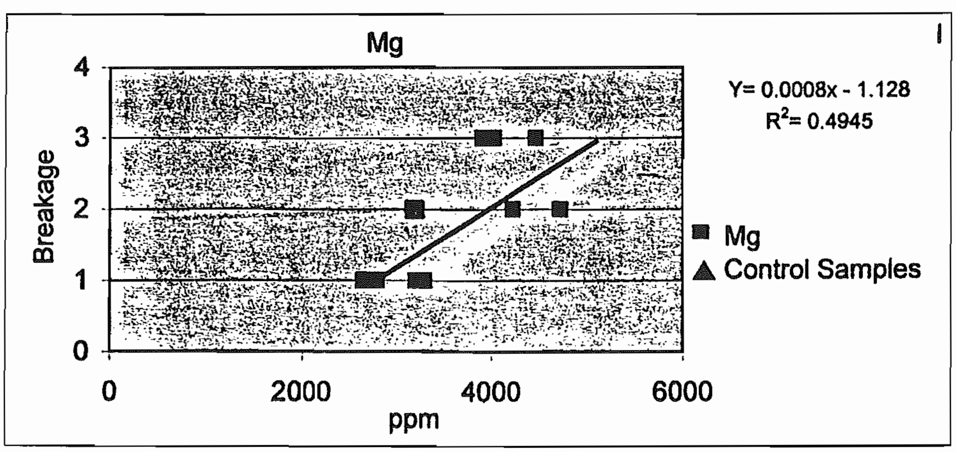

Sr
Y= 0.0053x + 0.4915
R^2= 0.2029
Breakage
4
3
2
1
0
0
200
400
600
ppm
Sr
Control Samples

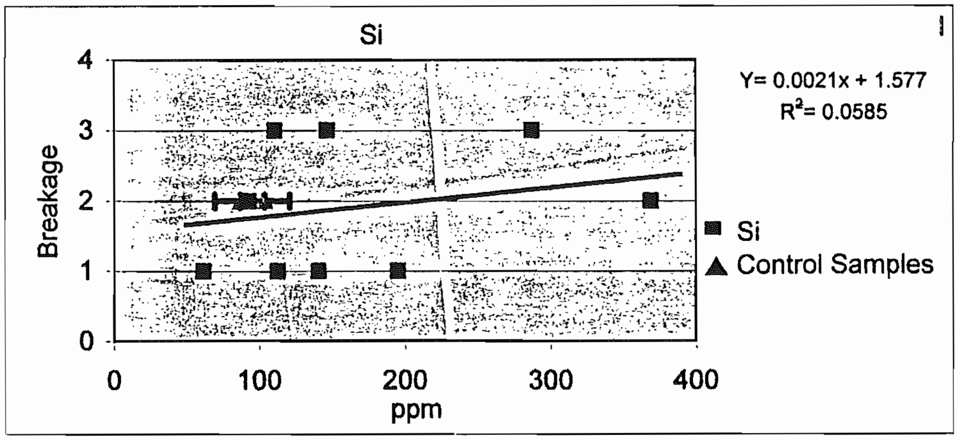

Ti
Y= -0.0117x + 2.8435
R^2= 0.0292
Breakage
4
3
2
1
0
0
50
100
150
ppm
Ti
Control Samples

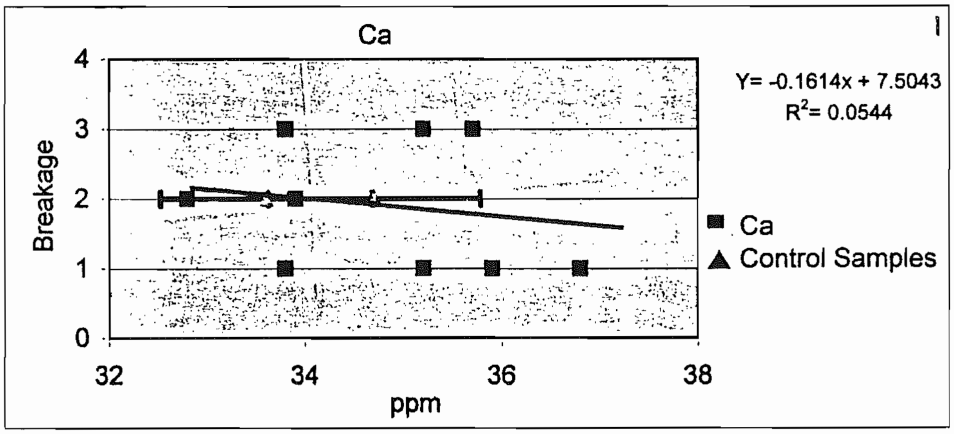

V
Breakage
ppm
Y= 1.2479x + 1.4459
R^2= 0.0481
V
Control Samples

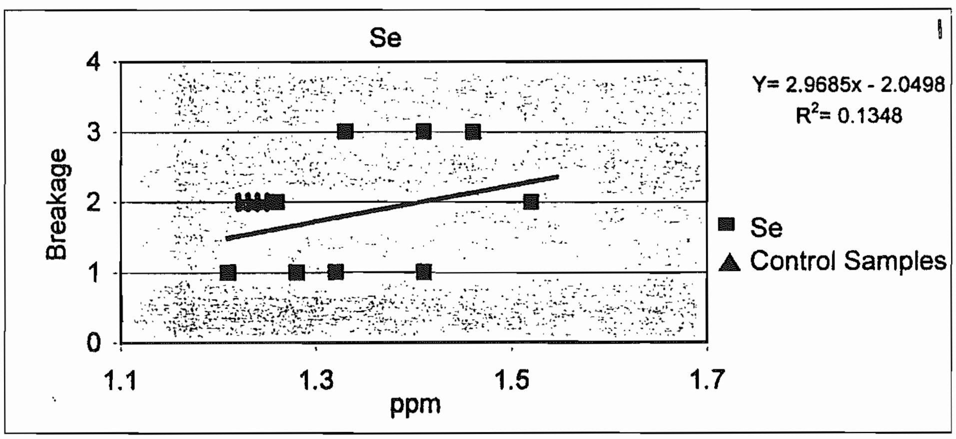

Zn
Breakage
ppm
Y= 0.0216x + 0.7595
R^2= 0.1739
Zn
Control Samples

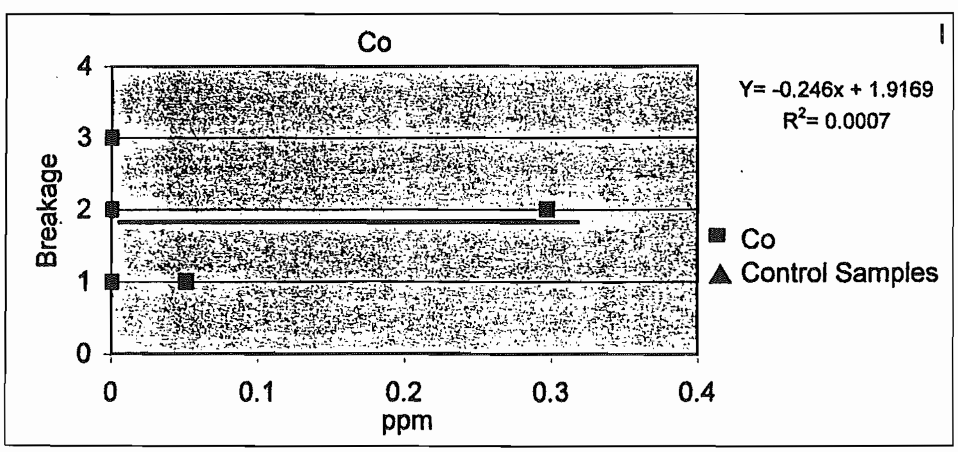

Be
Breakage
ppm
Y= 27.36x + 1.4278
R^2= 0.0677
Be
Control Samples

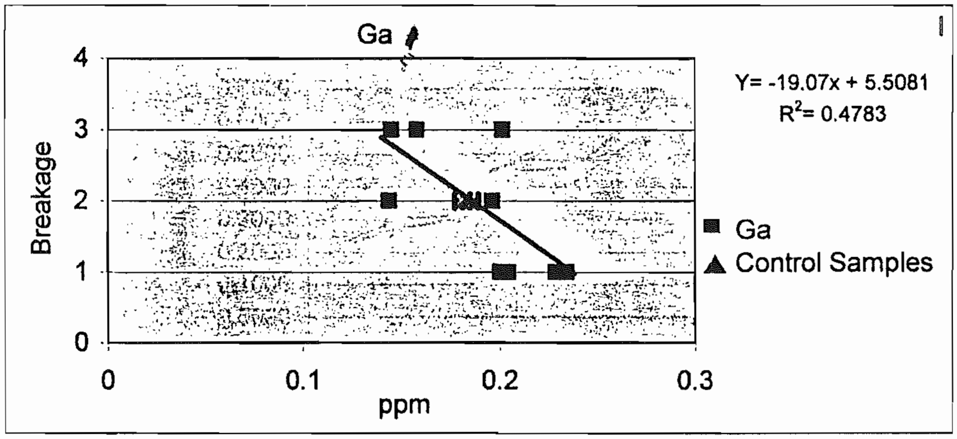

Mg
Breakage
ppm
Y= 0.0008x - 1.128
R^2= 0.4945
Mg
Control Samples

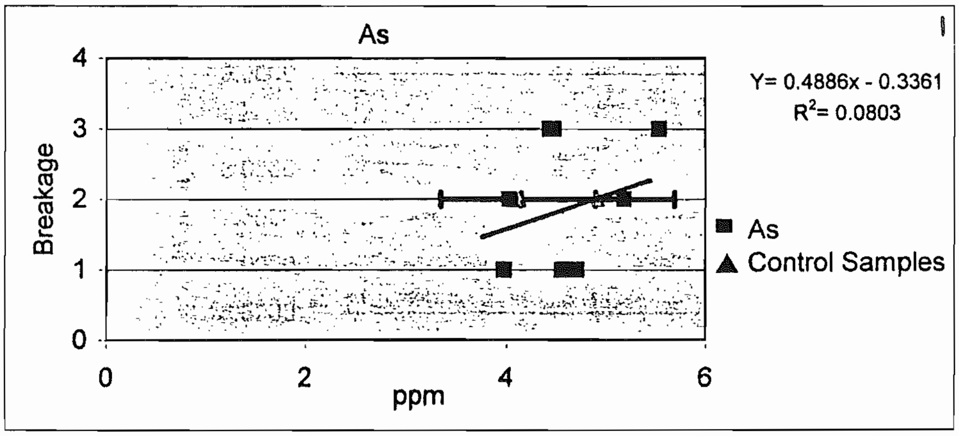

Si
Breakage
ppm
Y= 0.0021x + 1.577
R^2= 0.0585
Si
Control Samples

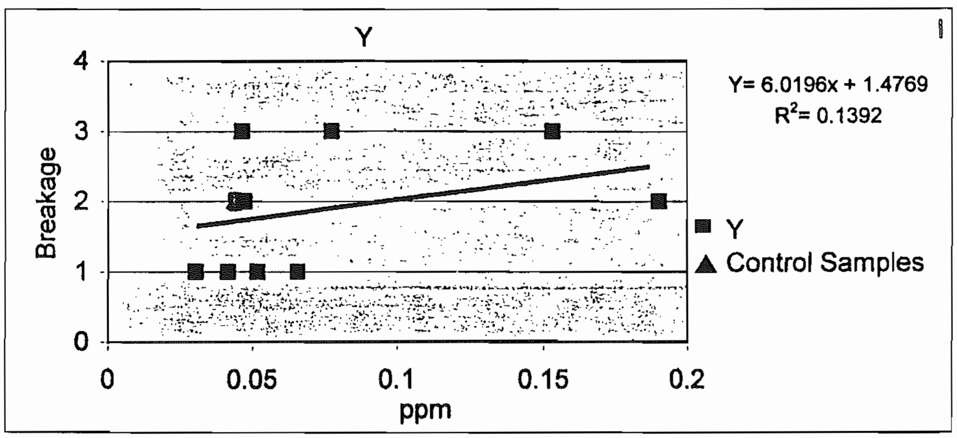

Ca
Breakage
ppm
Y= -0.1614x + 7.5043
R^2= 0.0544
Ca
Control Samples

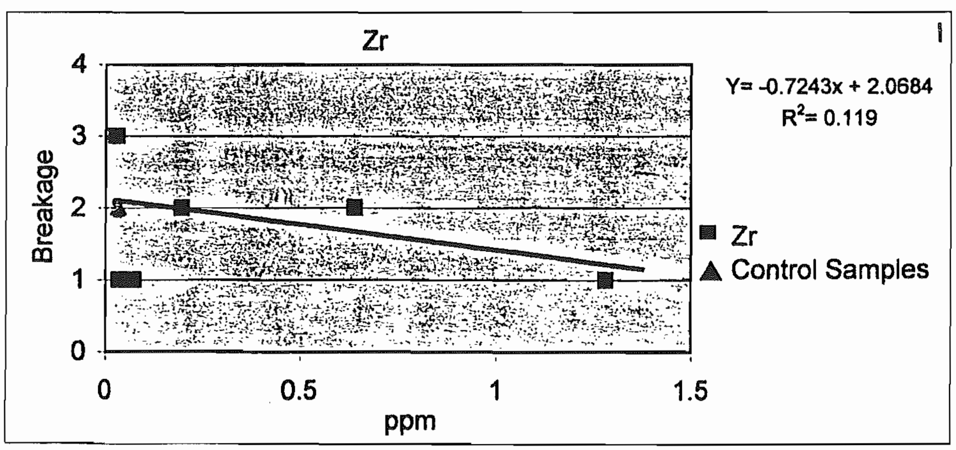

Se
Breakage
ppm
Y= 2.9685x - 2.0498
R^2= 0.1348
Se
Control Samples

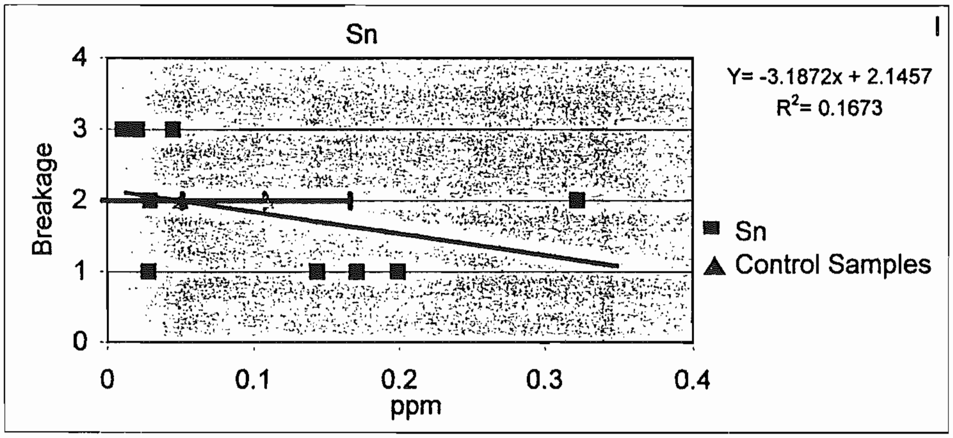

Co
Breakage
ppm
Y= -0.246x + 1.9169
R^2= 0.0007
Co
Control Samples

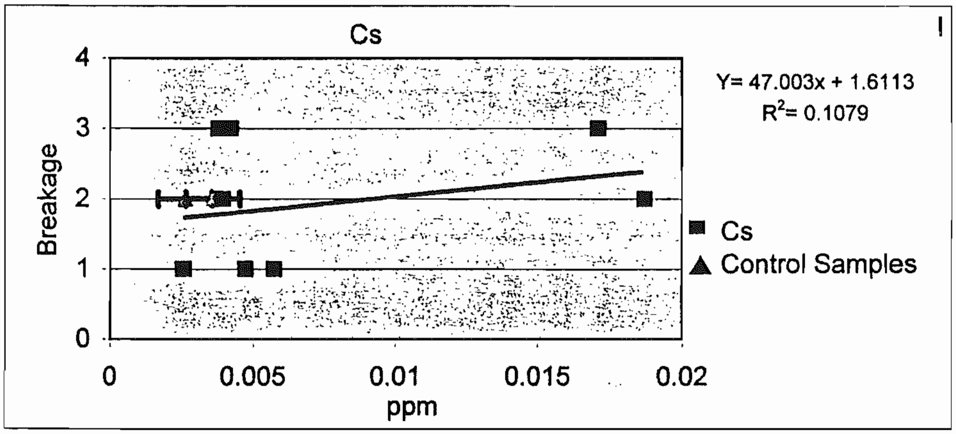

Ga
4
3
2
1
0
Breakage
0
0.1
0.2
0.3
ppm
Y= -19.07x + 5.5081
R^2= 0.4783
Ga
Control Samples

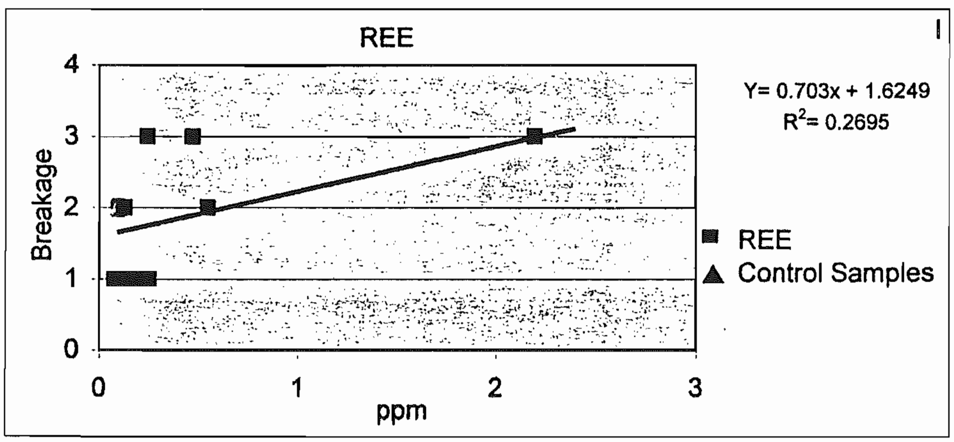

As
4
3
2
1
0
Breakage
0
2
4
6
ppm
Y= 0.4886x - 0.3361
R^2= 0.0803
As
Control Samples

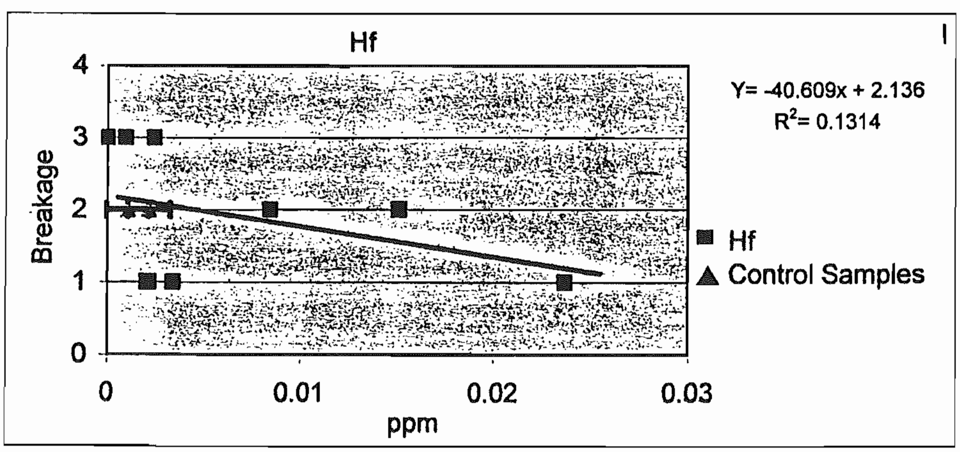

Y
4
3
2
1
0
Breakage
0
0.05
0.1
0.15
0.2
ppm
Y= 6.0196x + 1.4769
R^2= 0.1392
Y
Control Samples

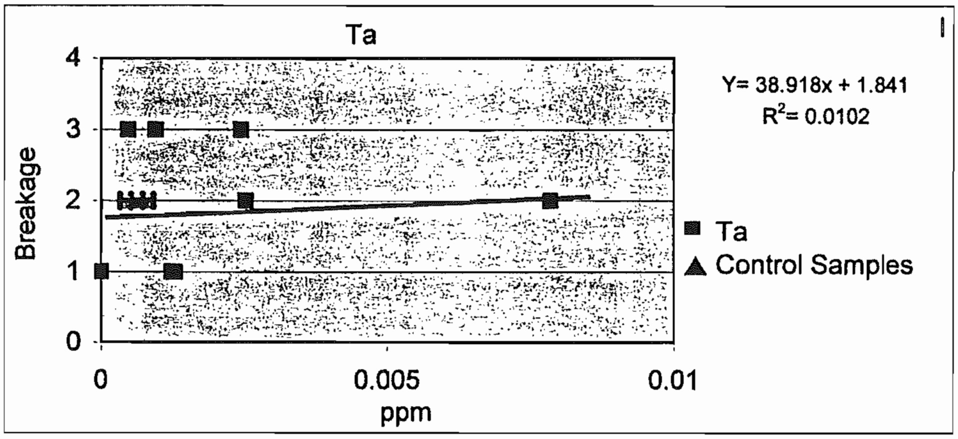

Zr
4
3
2
1
0
Breakage
0
0.5
1
1.5
ppm
Y= -0.7243x + 2.0684
R^2= 0.119
Zr
Control Samples

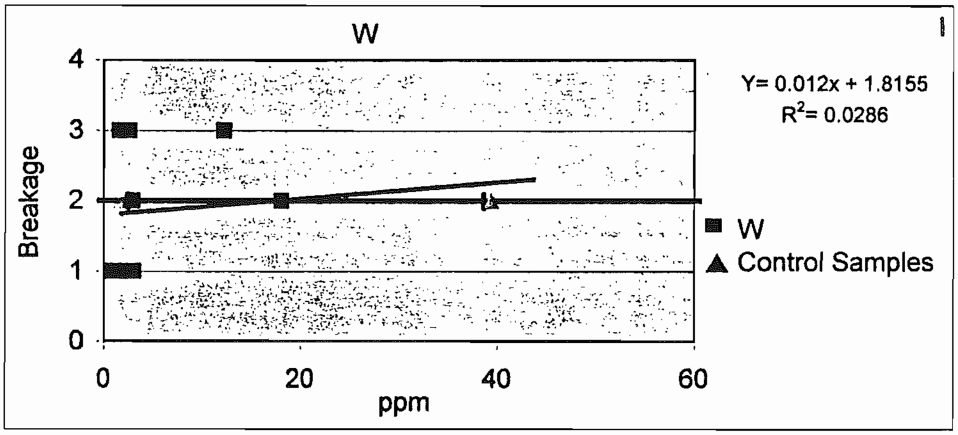

Sn
Y= -3.1872x + 2.1457
R2= 0.1673
Breakage
ppm
Sn
Control Samples

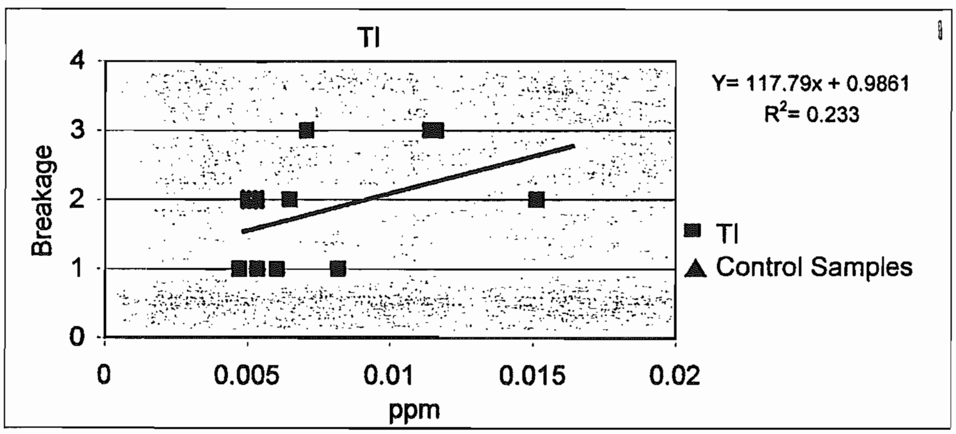

Cs
Y= 47.003x + 1.6113
R2= 0.1079
Breakage
ppm
Cs
Control Samples

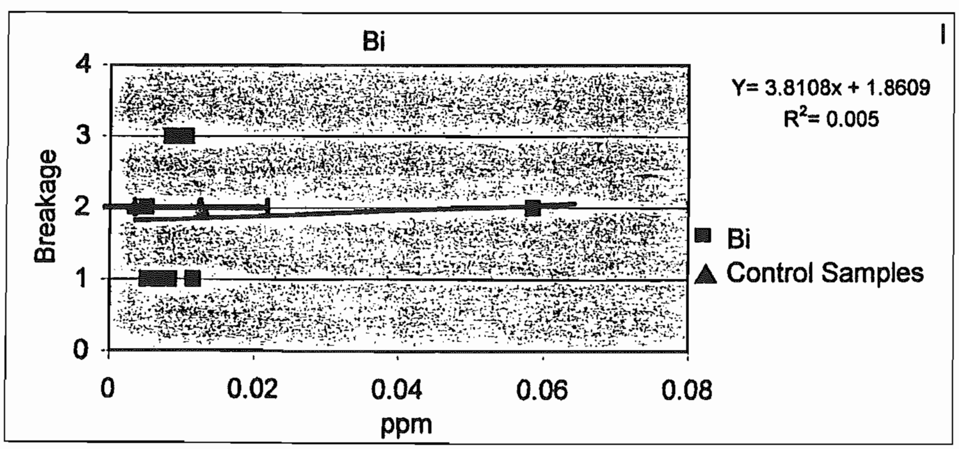

REE
Y= 0.703x + 1.6249
R2= 0.2695
Breakage
ppm
REE
Control Samples

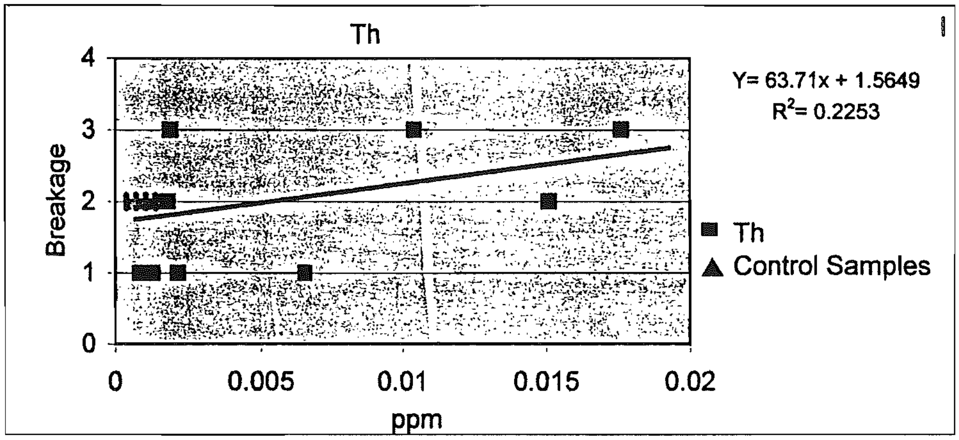

Hf
Y= -40.609x + 2.136
R2= 0.1314
Breakage
ppm
Hf
Control Samples

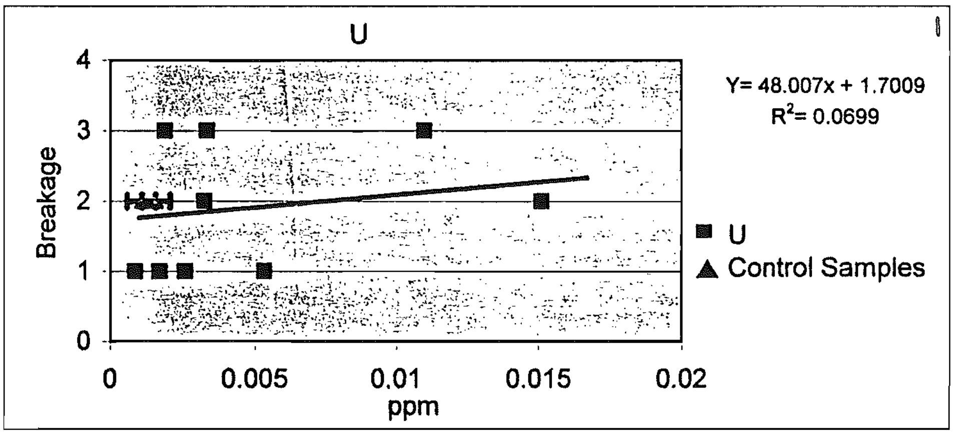

Ta
Breakage
4
3
2
1
0
0
0.005
0.01
ppm
Y= 38.918x + 1.841
R2= 0.0102
Ta
Control Samples


W
Breakage
4
3
2
1
0
0
20
40
60
ppm
Y= 0.012x + 1.8155
R2= 0.0286
W
Control Samples


Tl
Breakage
4
3
2
1
0
0
0.005
0.01
0.015
0.02
ppm
Y= 117.79x + 0.9861
R2= 0.233
Tl
Control Samples


Bi
Breakage
4
3
2
1
0
0
0.02
0.04
0.06
0.08
ppm
Y= 3.8108x + 1.8609
R2= 0.005
Bi
Control Samples


Th
4
3
2
1
0
Breakage
0
0.005
0.01
0.015
0.02
ppm
Y= 63.71x + 1.5649
R2= 0.2253
Th
Control Samples


U
4
3
2
1
0
Breakage
0
0.005
0.01
0.015
0.02
ppm
Y= 48.007x + 1.7009
R2= 0.0699
U
Control Samples

Appendix H: Microprobe data for moose teeth samples

Sample: M056

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.0939	39.7997	0.7486	0.1984	0.2233	0.0000	0.0000	48.2798	0.0187	0.0289	107.3913
18.0526	38.8891	0.6890	0.1676	0.3016	0.0000	0.0000	47.9445	0.0000	0.0447	106.0891
18.0075	38.3668	0.7109	0.1725	0.3169	0.0000	0.0000	45.6269	0.0111	0.0307	103.2432
18.4495	38.1659	0.6276	0.1450	0.4485	0.0000	0.0000	45.3068	0.0026	0.0400	103.1859
18.2682	39.7790	0.6116	0.1561	0.4627	0.0000	0.0000	46.6130	0.0161	0.0229	105.9295

Sample: M053

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.1230	38.4656	0.6136	0.2102	0.3869	0.0000	0.0000	46.1806	0.0212	0.0230	104.0241
18.3346	38.9433	0.6496	0.2207	0.3772	0.0000	0.0000	47.8889	0.0085	0.0285	106.4513
18.4903	38.8505	0.7051	0.2300	0.3781	0.0000	0.0000	47.9501	0.0255	0.0406	106.6701
18.1579	37.6285	0.6492	0.2093	0.3572	0.0000	0.0000	45.7623	0.0281	0.0295	102.8220
18.1689	38.9375	0.6525	0.2149	0.3573	0.0000	0.0000	47.7674	0.0127	0.0258	106.1369
18.2758	38.1379	0.6795	0.2217	0.3581	0.0000	0.0000	45.8613	0.0060	0.0480	103.5882

Sample: M052

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.3896	37.5155	0.7362	0.1674	0.2437	0.0000	0.0000	47.3534	0.0145	0.0174	104.4376
18.2155	38.0838	0.6927	0.1701	0.3114	0.0000	0.0000	46.2920	0.0068	0.0378	103.8101
18.3133	38.8030	0.6613	0.1819	0.3375	0.0000	0.0000	47.3295	0.0102	0.0323	105.6690
18.1650	38.5022	0.6369	0.1712	0.4075	0.0000	0.0000	46.6680	0.0127	0.0137	104.5772
18.0183	38.6541	0.6060	0.1494	0.4713	0.0000	0.0000	46.1876	0.0076	0.0341	104.1283
18.4279	38.1244	0.6042	0.1216	0.5509	0.0000	0.0000	45.7362	0.0145	0.0239	103.6036

Sample: M051

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
17.3373	34.2998	0.9727	0.2020	0.1265	0.0000	0.0000	50.5963	0.0338	0.0307	103.5990
17.7384	39.3477	0.7455	0.1513	0.3091	0.0000	0.0000	48.8035	0.0177	0.0230	107.1361
17.5904	39.1714	0.7871	0.1593	0.3815	0.0000	0.0000	48.3569	0.0025	0.0157	106.4648
17.5511	39.4119	0.6899	0.1709	0.4230	0.0000	0.0000	48.1471	0.0059	0.0515	106.4512
17.7509	39.2512	0.6895	0.1345	0.4312	0.0000	0.0000	48.0650	0.0168	0.0157	106.3547
17.9104	39.4720	0.6506	0.1366	0.5042	0.0000	0.0000	47.9336	0.0160	0.0451	106.6684

Sample: M042

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
17.3939	39.1049	0.7285	0.2177	0.3874	0.0000	0.0000	48.1745	0.0084	0.0414	106.0566
17.5297	38.7635	0.6607	0.2477	0.3702	0.0000	0.0000	47.8456	0.0219	0.0368	105.4760
17.4064	38.4961	0.7023	0.3034	0.3637	0.0000	0.0000	47.6162	0.0143	0.0414	104.9437
17.1155	39.1212	0.6392	0.2606	0.3486	0.0000	0.0000	48.8260	0.0160	0.0203	106.3473
17.2585	38.8647	0.6548	0.2687	0.3118	0.0000	0.0000	48.6871	0.0118	0.0212	106.0785
16.8830	38.5418	0.6544	0.2267	0.3085	0.0000	0.0000	46.9347	0.0403	0.0359	103.6252

Sample: M027

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
17.4194	38.7963	0.7556	0.1390	0.2197	0.0000	0.0000	47.9897	0.0235	0.0295	105.3727
17.4865	38.9408	0.7206	0.1322	0.2735	0.0000	0.0000	47.7947	0.0319	0.0359	105.4160
17.7179	38.9774	0.6864	0.1859	0.3034	0.0000	0.0000	47.2601	0.0177	0.0341	105.1829
17.6059	39.3754	0.6428	0.2192	0.3477	0.0000	0.0000	47.5507	0.0294	0.0487	105.8197
17.4217	39.5122	0.6450	0.1635	0.4340	0.0000	0.0000	47.0013	0.0277	0.0542	105.2596
17.5663	39.7118	0.4901	0.1271	0.5560	0.0000	0.0000	47.1836	0.0302	0.0423	105.7073

Sample: M041

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
17.6538	39.0005	0.6364	0.1716	0.4130	0.0000	0.0000	46.8756	0.0084	0.0230	104.7822
17.4204	38.6509	0.6576	0.1781	0.4099	0.0000	0.0000	46.6383	0.0059	0.0148	103.9759
18.2251	39.2061	0.6275	0.2001	0.3907	0.0000	0.0000	48.5331	0.0008	0.0257	107.2091
18.6780	38.6133	0.7226	0.1881	0.3630	0.0000	0.0000	47.0886	0.0152	0.0156	105.6843
18.5156	39.0053	0.7059	0.1933	0.3705	0.0000	0.0000	47.9442	0.0000	0.0018	106.7365
18.1299	38.2186	0.6840	0.2083	0.3466	0.0000	0.0000	46.7339	0.0008	0.0138	104.3359

Sample: M016

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.4141	38.7299	0.7544	0.1787	0.3108	0.0000	0.0000	46.9951	0.0303	0.0395	105.4527
18.0656	38.3061	0.7265	0.1931	0.3026	0.0000	0.0000	47.7074	0.0269	0.0257	105.3539
18.5588	38.8143	0.7075	0.1739	0.3116	0.0000	0.0000	47.6145	0.0211	0.0377	106.2393
18.0868	38.2046	0.7171	0.1831	0.3033	0.0000	0.0000	47.0495	0.0210	0.0460	104.6114
18.2201	38.4662	0.7476	0.1883	0.3144	0.0000	0.0000	47.8515	0.0177	0.0193	105.8251
18.3106	38.4270	0.7517	0.1829	0.3116	0.0000	0.0000	47.6462	0.0084	0.0340	105.6723

Sample: M012

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.0747	38.0391	0.6676	0.2125	0.3512	0.0000	0.0000	47.4662	0.0093	0.0487	104.8692
17.8800	38.0776	0.6455	0.2067	0.3801	0.0000	0.0000	46.3972	0.0000	0.0202	103.6072
18.5623	38.8417	0.6670	0.2227	0.4090	0.0000	0.0000	47.3173	0.0000	0.0460	106.0659
18.0782	38.7859	0.6217	0.2123	0.4855	0.0000	0.0000	46.1206	0.0000	0.0505	104.3546
18.3084	37.9846	0.5980	0.2106	0.4761	0.0000	0.0000	46.7203	0.0135	0.0368	104.3482
18.5416	38.8380	0.5081	0.1373	0.6238	0.0000	0.0000	45.9613	0.0000	0.0211	104.6311

Sample: M022

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.9018	38.1494	0.7089	0.4057	0.2956	0.0000	0.0000	47.2216	0.0000	0.0276	105.7105
18.6642	38.3168	0.7016	0.2872	0.3282	0.0000	0.0000	47.2569	0.0000	0.0230	105.5779
18.3521	37.8213	0.6816	0.2593	0.3141	0.0000	0.0000	47.3135	0.0008	0.0101	104.7527
18.3786	38.3922	0.6559	0.2692	0.3220	0.0000	0.0000	48.5694	0.0000	0.0230	106.6102
18.7003	34.4399	0.6770	0.2496	0.3408	0.0000	0.0000	48.3430	0.0076	0.0105	102.7686
18.2386	38.7169	0.7063	0.3435	0.3491	0.0000	0.0000	46.6486	0.0126	0.0370	105.0525

Sample: M030

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
17.9329	38.7237	0.7587	0.2413	0.2328	0.0000	0.0000	47.4801	0.0000	0.0241	105.3935
17.4484	37.6343	0.7456	0.2218	0.2737	0.0000	0.0000	44.6506	0.0034	0.0553	101.0331
17.3972	36.3000	0.7600	0.2182	0.2509	0.0000	0.0000	46.2872	0.0135	0.0260	101.2529
14.7926	28.6072	0.6839	0.1994	0.2081	0.0000	0.0000	45.1165	0.0000	0.0000	89.6077
16.1659	31.2796	0.6696	0.2185	0.2428	0.0000	0.0000	45.4179	0.0000	0.0253	94.0197
18.3265	38.4317	0.7039	0.2944	0.3269	0.0000	0.0000	46.4043	0.0000	0.0242	104.5118

Sample: M003

Ca	Na	Mg	Cl	N	F	O	S	K	Total	
18.7619	39.1338	0.6957	0.1752	0.4362	0.0000	0.0000	46.6895	0.0101	0.0747	105.9771
18.5867	39.0519	0.6984	0.1690	0.4062	0.0000	0.0000	46.8238	0.0126	0.0196	105.7681
18.7917	39.1456	0.6707	0.1777	0.4269	0.0000	0.0000	46.5465	0.0042	0.0526	105.8158
17.1347	35.2549	0.7041	0.1512	0.3550	0.0000	0.0000	46.2802	0.0000	0.0463	99.9265
17.5874	35.6373	0.6975	0.1649	0.3747	0.0000	0.0000	45.4832	0.0000	0.0583	100.0032
18.4031	39.0671	0.7034	0.1847	0.4098	0.0000	0.0000	46.1472	0.0008	0.0370	104.9530

Appendix I: Plotted Graphs for Microprobe Data

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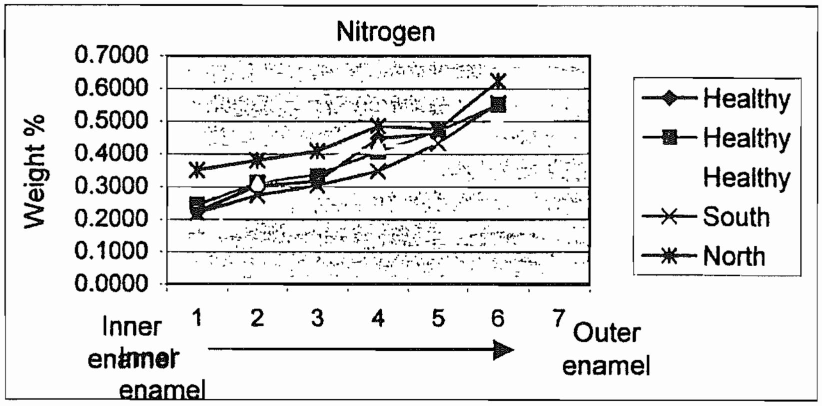
February 26, 2004

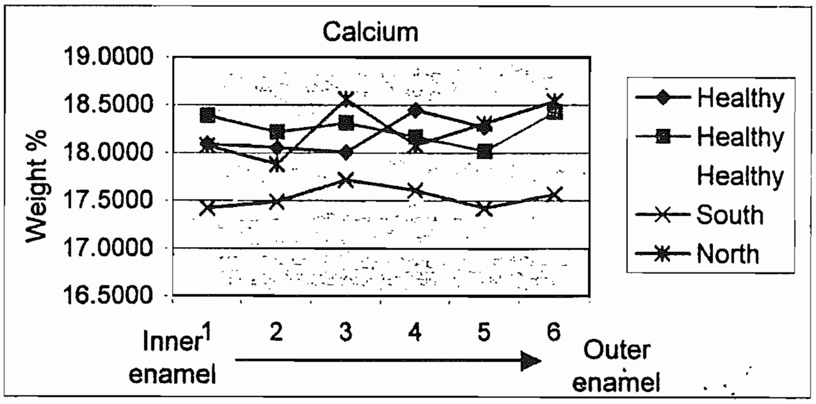
Department of Earth Sciences
Dalhousie University

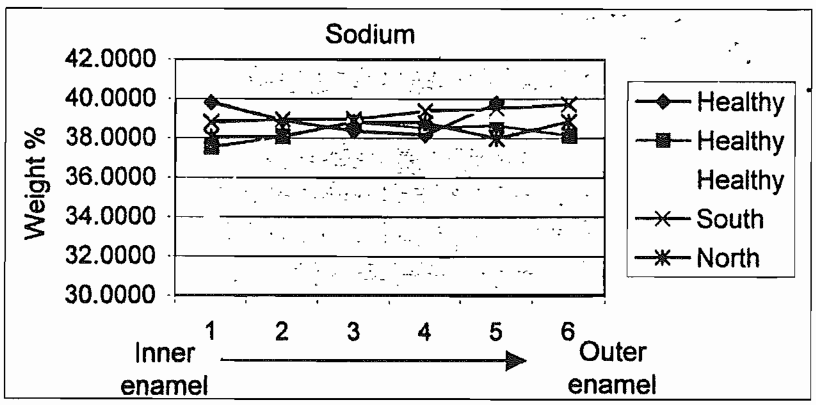
Attention: Dr. M. Zentilli

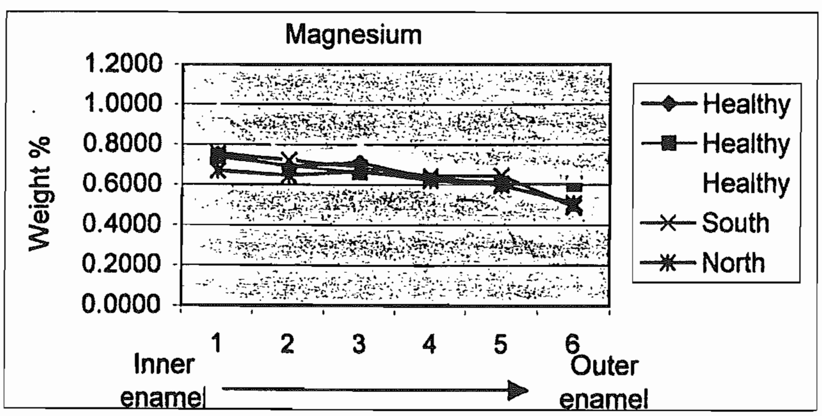
Re: Results of analysis on submitted samples.

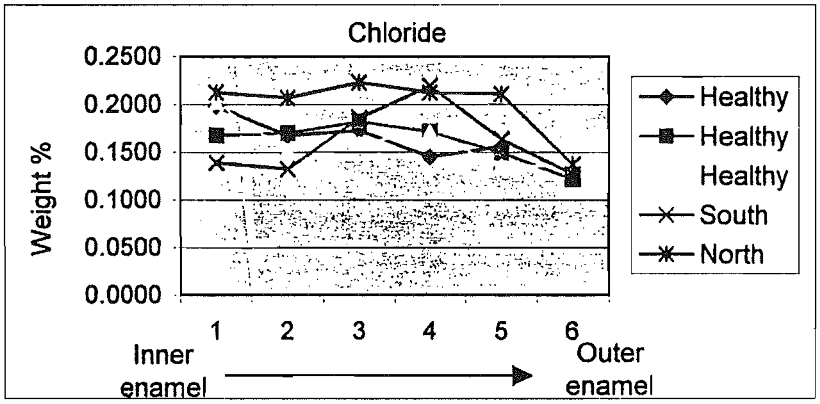
	Sample					
	T-1	T-2	T-3	T-4	T-5	T-6
Si (%)	0.15	0.84	0.24	0.22	0.21	0.11
Ti (%)	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Al (%)	0.025	0.046	0.021	0.042	0.017	0.023
Mg (%)	0.34	0.27	0.34	0.44	0.46	0.53
Ca (%)	26.00	24.94	26.95	27.11	27.46	29.10
Na (%)	0.24	0.22	0.25	0.26	0.27	0.36
P (%)	9.82	9.43	9.78	9.73	9.95	9.99
C(Total)(%)	18.37	18.56	17.93	17.88	17.61	16.74
As (ppm)	4	4	2	5	4	4
Ba (ppm)	260	220	230	240	220	240
Be (ppm)	<1	<1	<1	<1	<1	<1
Cd (ppm)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Co (ppm)	<1	<1	<1	<1	<1	<1
Cr (ppm)	14	30	19	15	18	22
Cu (ppm)	4	5	5	3	5	5
Fe (ppm)	844	1950	1200	838	1060	1170
K (ppm)	95	87	84	67	65	134
Li (ppm)	4	3	5	5	5	5
Mn (ppm)	37	62	59	88	89	42
Mo (ppm)	<1	<1	<1	<1	<1	<1
Ni (ppm)	2	4	3	2	1	1
Pb (ppm)	6	5	<2	<2	6	<2
Rb (ppm)	6	8	5	6	3	5
Sr (ppm)	285	264	315	318	331	313
V (ppm)	8	9	9	8	9	7
Zn (ppm)	113	104	101	100	100	100

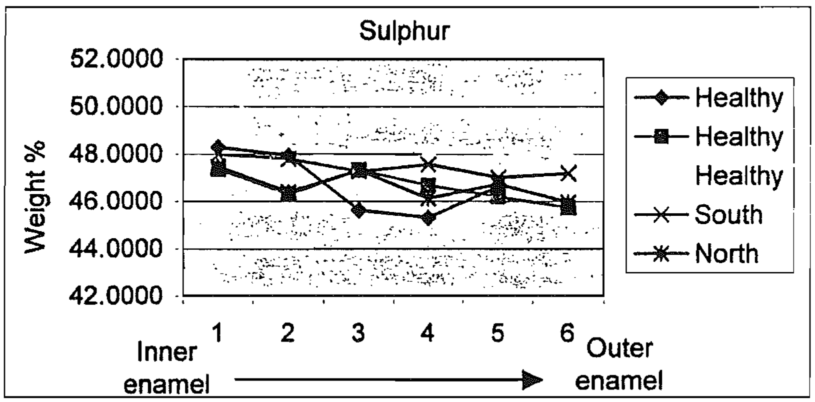

Nitrogen
Weight %
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
1
2
3
4
5
6
7
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North

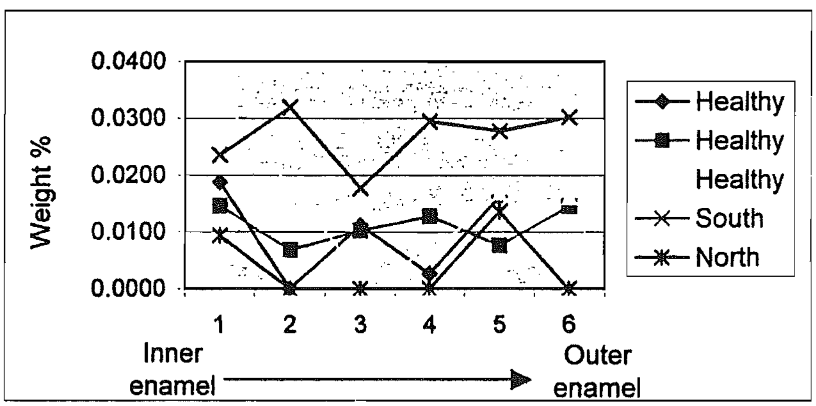

Calcium
Weight %
19.0000
18.5000
18.0000
17.5000
17.0000
16.5000
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North


Sodium
Weight %
42.0000
40.0000
38.0000
36.0000
34.0000
32.0000
30.0000
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North


Magnesium
Weight %
1.2000
1.0000
0.8000
0.6000
0.4000
0.2000
0.0000
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North


Chloride
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Weight %
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North


Sulphur
52.0000
50.0000
48.0000
46.0000
44.0000
42.0000
Weight %
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North


0.0400
0.0300
0.0200
0.0100
0.0000
Weight %
1
2
3
4
5
6
Inner enamel
Outer enamel
Healthy
Healthy
Healthy
South
North

	Sample					
	W-1	W-2	W-3	W-4	W-5	W-6
Si (%)	0.12	0.34	0.29	0.28	0.21	0.18
Ti (%)	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Al (%)	0.035	0.030	0.013	0.011	0.011	0.014
Mg (%)	0.30	0.26	0.26	0.28	0.29	0.31
Ca (%)	16.70	15.92	15.31	17.45	10.57	17.80
Na (%)	0.19	0.16	0.18	0.28	0.30	0.36
P (%)	6.81	6.37	5.78	6.33	5.94	6.76
C(Total)(%)	27.12	29.74	30.09	28.67	29.80	28.11
As (ppm)	2	3	2	3	8	2
Ba (ppm)	380	380	340	340	350	350
Be (ppm)	<1	<1	<1	<1	<1	<1
Cd (ppm)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Co (ppm)	<1	<1	<1	<1	<1	<1
Cr (ppm)	12	24	24	29	19	19
Cu (ppm)	4	5	6	5	4	3
Fe (ppm)	568	1470	1610	1830	1180	1010
K (ppm)	104	75	158	288	293	309
Li (ppm)	3	3	3	3	3	3
Mn (ppm)	14	17	18	17	17	15
Mo (ppm)	<1	<1	<1	<1	<1	<1
Ni (ppm)	<1	<1	2	3	5	2
Pb (ppm)	4	4	2	3	2	3
Rb (ppm)	2	2	2	4	4	4
Sr (ppm)	366	358	361	403	381	408
V (ppm)	8	5	6	9	8	7
Zn (ppm)	113	109	96	99	100	103

Cyril Cole